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Project Completion
Report No. 552

# Preliminary Estimate of Ground-Water Recharge Rates, Related Streamflow and Water Quality in Ohio

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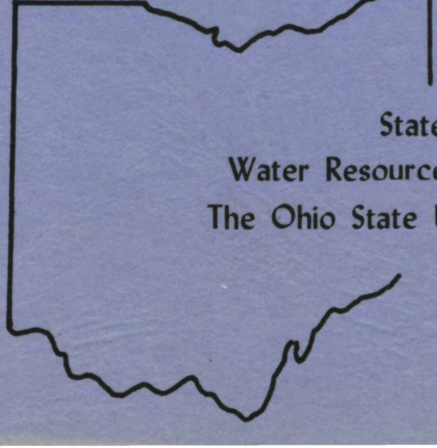
1979

United States
Department of the Interior

Contract No.
A-051-Ohio



State of Ohio
Water Resources Center
The Ohio State University

# PRELIMINARY ESTIMATE OF
# REGIONAL EFFECTIVE GROUND-WATER RECHARGE RATES
# IN OHIO

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This study was supported by the
Office of Water Research and Technology
U.S. Department of the Interior
under Project A-051-OHIO

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

Page No.

## Chapter 1

# EVALUATION OF GROUND-WATER RECHARGE

## Introduction

One of the major unknowns in any hydrogeologic investigation is the rate at which water infiltrates from the land surface to the water table. That small percentage of rainfall and snowmelt that eventually arrives at the water table and increases the quantity of ground water in storage is called ground-water recharge. In humid regions most of the annual ground-water recharge eventually discharges into streams or is removed by evapotransperation. There is a long term balance between recharge and discharge and in an unstressed aquifer the amount of water continually in storage is nearly constant. The rate of ground-water recharge depends on several factors, including precipitation, permeability of the rocks, depth to water table, soil type and moisture conditions, topography, vegetation type and density, and temperature, among many others.

Not all ground-water recharge finds its way to a nearby stream. During the growing season a large percentage of the shallow water, either in the capillary fringe or below the water table but within the zone of root penetration, is removed by plants (transpiration). Some is lost to the atmosphere by evaporation. Another part may percolate to deeper deposits, eventually to discharge elsewhere. Furthermore, an additional amount is removed by wells, and perhaps through springs and seeps. Strictly speaking, bank storage probably should not be considered a component of regional ground-water recharge. In reality, much of the water held in bank storage remains in the ground only a few hours or days at most, yet it is commonly considered ground-water runoff in various hydrograph separation schemes.

In this reconnaissance investigation the term "effective ground-water recharge" is used. Effective ground-water recharge is herein defined as the total quantity of water that originates from downward infiltration to the water table and upward leakage from deeper zones to the surficial aquifer and then eventually finds its way to a nearby stream. It is synonymous with ground-water runoff. Thus by this definition, effective ground-water recharge represents only the liquid residual that reaches a stream. This volume is smaller than the total annual quantity of recharge, which is depleted largely be evapotranspiration.

Because of all the variables and difficulties involved in attempting to determine ground-water recharge rates, experiments along these lines have been relatively few and several of these exceedingly complex. Nonetheless, particularly in the design of well fields, recharge rates can be of considerable importance because the recharge that can be captured by the cone of depression surrounding a pumping well is equal or nearly equal to the long-term yield that the well can provide without drawing from storage.

In addition to scientific curiosity and well-field design, a knowledge of the range in recharge rates could become important to planners and regulatory agencies as they attempt to better manage the development of a region's water resources and urban-suburban sprawl. For example, many developers are attempting to locate a dense population in a relatively small space. Commonly these suburban developments are located so far from existing municipal water and sewage lines that each new home must have its own water supply and waste disposal system. Let us assume that a developer requests a permit to build single-family dwellings on half-acre lots in an area where moderately thick glacial till, containing scattered layers of sand and gravel, overlies a thick deposit of shale. Let us further assume that each house will contain an average of four individuals and that the daily water demand, supplied from a well, will average 55 gpd/person. Should the permit be granted?

During a year of normal precipitation in Ohio where the geologic conditions are as described above, the annual effective regional ground-water recharge rate for an open area might average about 130,000 gpd/sq. mi. and would decline to perhaps less than 80,000 gpd/sq. mi. during periods of below normal precipitation. The water demand for a development encompassing one square mile and filled to capacity, would require about 282,000 gpd, a rate that exceeds the normal recharge rate by more than a factor of 2. Furthermore, the volume of recharge would be considerably reduced with time because much of the ground would be covered by impermeable structures, such as buildings, streets, sidewalks and driveways, and surface runoff would be promoted by gutters, storm drains, culverts and landscaping. Clearly, in this instance water levels would decline quickly and water availability would become a serious problem. The permit should not be granted.

## Purpose and Scope

The entire State of Ohio was examined during this investigation because it offers a wide variety of hydrogeologic conditions. About two thirds of the State are covered with glacial drift and the relief is generally low. In some areas the drift is thick but elsewhere it is so thin that bedrock crops out in some stream channels. Also within the State are several extensive deposits of outwash that form major aquifers, particularly along the Mad, Great Miami, Scioto, Hocking, Tuscarawas and Muskingum Rivers.

Throughout most of the southeastern third of Ohio, bedrock forms the surface and the relief ranges from nearly flat grasslands to high timber-covered hills. In much of this region, relatively thin alternating layers of sandstone, shale, coal and limestone of Late Paleozoic age crop out. To the extreme southwest, in the dissected Cincinnati region, thin layers of limestone and shale of Ordovician age predominate. Nearly bisecting the State is a belt, about 20 miles wide, that consists largely of shale of Silurian and Devonian age, which, although covered by till in the uplands, crops out along hillsides and in stream valleys. Clearly, a wide variety of rock units, topography, and hydrogeologic conditions lie within Ohio.

The primary purpose of this investigation is to develop, for each of the 12 major drainage basins in Ohio a generalized map that indicates effective ground-water recharge rates. Complementing each map are data and tables that relate the effective recharge rate to flow-duration curves, the 90 percent flow, and flow ratios.

Ground-water quality changes both laterally and vertically within the same hydrologic unit and from unit to unit, but at any particular place in a specific hydrologic unit that is unaffected by man's activities, the quality remains relatively uniform from one year to the next. At the present time, maps that show the distribution and concentration of selected chemical parameters in shallow aquifers in Ohio are not available.

One of the assumptions on which this investigation is based is that the chemical quality of uncontaminated streams at low flow indicates the quality of water in shallow aquifers that lie in the zone of intensive circulation. If this assumption is correct, then a stream is analogous to an extremely long, but shallow, horizontal well and, therefore, a sample of water from a stream during low-flow periods should provide a good estimation of the quality of the shallow ground water in the basin.

Based on these assumptions, another purpose of the investigation was to construct a series of maps that show regional changes in quality in shallow ground-water reservoirs. Maps of this nature indicate the type of water to be expected within a particular region and can be used to estimate the kind of treatment, if any, that would be either required or prove beneficial.

## Methods of Investigation

The hydrologic rationale on which this study is based is described in Chapter 2. This investigation is preliminary, generalized and regional in nature. Its cornerstone is a series of water quality-duration curves and tables, flow-duration curves and tables, and stream hydrographs and discharge tables. All of the analyses are based on a number of digital computer programs that manipulate easily obtainable streamflow records. The data interpretations are preliminary and must remain so until the assumptions on which the analyses are based are validated.

The principal computer program developed during this research plots a flow-duration curve and a stream hydrograph. It also separates the hydrograph into surface runoff and ground-water runoff by three different methods and then calculates (1) the annual percentage of runoff that consists of ground-water runoff, (2) the monthly rate of ground-water runoff and (3) the annual effective ground-water recharge rate. The programs are described in Chapter 3.

Traditional hydrograph separation techniques generally rely on the extremely time consuming process of manual separation. Admittedly, manual procedures allow a greater latitude for interpretation, but for regional investigations such as this, the great savings in both time and money permitted by automatic data processing may serve to override the benefits obtained by more laborious methods.

Data used in this study were obtained from published reports of the U.S. Geological Survey, specifically Water Resources Data for Ohio, Part I, Surface Water Records, and Part II, Water Quality Data. Streamflow records chosen for this analysis include water years 1963, 1967, and 1973, which were years of low, normal, and high precipitation, respectively. These years were chosen in order to evaluate the effect on ground-water recharge during periods of maximum and minimum stress.

In addition to published streamflow and water-quality data, both published and unpublished records were searched in order to determine regional changes in ground-water quality in shallow aquifers so that the water-quality duration technique could be evaluated.

## Previous Work

Most previous investigators have determined ground-water runoff and recharge rates by (1) stream hydrograph separation, (2) flow-net analysis, (3) examination of the cone of depression surrounding a well field, and (4) by aquifer tests. The latter two methods imply that some stress has been applied to the hydrologic system and are not completely analogous to this investigation.

Only a few previous works will be cited here because a more detailed discussion will be provided by Henning (in progress). One of the earliest studies of ground-water runoff in the United States was the classic work by Meinzer and Sterns (1929) that described the Pomperaug Basin in Connecticut. Evaluating stream hydrographs and fluctuations of the water table, they determined that ground-water runoff contributed about 40 to 45 percent of the stream's total flow.

Harden and Drescher (1954) used flow nets to study ground-water recharge in Longlade County, Wisconsin and Rapp and others (1957) estimated a rate of about 33,000 gpd/sq. mi. in Goshen County, Wyoming, where precipitation averages only about 14 inches. Rasmussen and Andreasen (1959) prepared a hydrologic budget including ground-water recharge, for Beaverdam Creek, a small basin in the Maryland Coastal Plain. Their analysis was based on water-level fluctuations in wells.

Recharge to a thick permeable outwash deposit adjacent to the Mad River in west-central Ohio was investigated by Walton and Scudder (1960). They estimated that recharge was equal to about 12 inches (571,000 gpd/sq. mi.) during years of normal precipitation. Schicht and Walton (1961) described hydrologic budgets for three small basins in Illinois. In these till-mantled basins ground-water runoff ranges from 1.89 (90,000 gpd/sq. mi.) to 7.16 (341,000 gpd/sq. mi.) inches and ground-water recharge was estimated to range from a high of 8.03 (382,000 gpd/sq. mi.) to a low of only 3.89 (185,000 gpd/sq. mi.) inches.

The relation between ground water and surface water in Brandywine Creek was examined by Olmsted and Healy (1962). In this southeastern Pennsylvania basin, the geologic framework consists largely of metamorphic rocks. Recharge to a dolomite aquifer covered by a hundred feet or so of glacial till and less permeable dolomite in DuPage County, Illinois, was discussed by Zeizel and others (1962). Recharge rates, based on water levels and pumpage records, ranged between 64,000 and 158,000 gpd/sq. mi. Feth (1964) studied the discharge of water from tunnels in the Wasatch Mountains and related it to recharge and Walton (1965) summarized the results of several recharge studies in Illinois.

Several water-resource evaluation techniques, including seepage measurements, utilized in ground-water studies in New York were described by LaSala (1966). Ackroyd and others (1967) examined several basins in Minnesota and made substantial use of streamflow data. They determined ground-water runoff and related it to discharge ratios and basin characteristics. Johnson (1976) studied four small basins in the Delaware Coastal Plain. In these sandy areas, recharge determined by a winter base-flow method averaged about 15 (762,000 gpd/sq. mi) inches per year and ground-water runoff averaged about 13 (619,000 gpd/sq. mi.) inches. Precipitation is about 41 inches and ground-water runoff accounts for about 80 percent of runoff.

Ground-water runoff from several areas in the Scioto River basin in south-central Ohio was determined by Tuller (1974). Marvin (1975) examined the Maumee River basin in northwestern Ohio and used digital computer programs developed by Tuller (1974). Both Tuller and Marvin manually separated the stream hydrographs. On the other hand, Naymik (1977), who also evaluated ground-water recharge and runoff in the Maumee Basin, used an earlier version of the programs used in this study and, therefore, the separations were made automatically. There was little difference in the results determined by Marvin and Naymik.

Several individuals have examined the relation between surface water and ground water by means of water-quality data. The basis for this technique is the assumption that the concentration of specific chemical constituents in stream water during periods of low flow is the same as that in shallow ground-water reservoirs. Using these methods Kunkle (1965a, b), Toler (1965a, b) and Visocky (1970) determined ground-water runoff by separating stream hydrographs. LaSala (1966) described similar methods used in New York. Pettyjohn (1973) related anomalous chloride concentrations in central Ohio's Alum Creek to contamination of shallow aquifers by oil-field brine.

## CHAPTER 2

## THE GROUND-WATER -- SURFACE WATER INTERFACE

The interrelations between ground water and surface water are of great importance in both regional and local hydrogeologic investigations. A wide variety of information can be obtained by analyzing streamflow data because, at least in humid regions, ground-water runoff accounts for a significant part of a stream's total flow.

Over a long period the average annual ground-water runoff is equal to the effective recharge to the ground-water reservoir. Therefore, determination of the ground-water component of runoff by stream hydrograph separation makes it possible to establish the replenishment of ground water in the zone of intensive water circulation for entire or selected parts of river basins.

Ground-water runoff represents only the liquid residual and is not equivalent to the total ground-water recharge volume. During the growing season, the major component of aquifer discharge may be evapotranspiration and, in many cases, little or no ground water flows into streams. For the purpose of this report, the term "effective ground-water recharge rate" is used. It represents that quantity of water that leaks upward from deeper aquifers as well as that amount that infiltrates to the water table and eventually discharges into a stream. Although important, that quantity of ground water removed by evapotranspiration and pumping, which does not contribute to runoff, is excluded.

Streamflow may consist of several components including ground-water runoff, surface runoff, effluent and precipitation that falls directly into the channel. The volume of water added by precipitation that falls directly into the channel is relatively small compared to the stream's total flow. The contribution by waste effluent may or may not be significant, since it depends on the activities that are occurring in the basin. In permeable basins in humid regions, ground-water runoff may account for 70 to 80 percent of the stream's annual discharge. The remainder is largely surface runoff, which, originating as precipitation or snow melt, flows directly into the stream channel.

Under natural conditions a gaining stream, one that increases in discharge downstream, occurs where the water table is above the base of the stream channel. Along a losing stream, the water table is lower than the stream stage, water seeps through the channel sides and bottom, and the discharge decreases downstream. Of course, the water table fluctuates throughout the year in response to differences in ground-water recharge and discharge, but normally it is highest in the spring, the major period of ground-water recharge. From spring to fall, ground-water recharge occurs only intermittently and the amount of water in aquifer storage is slowly depleted because of ground-water runoff, evapotranspiration and pumping.

In the case of a perennial stream, the water table declines but not to such an extent that streamflow ceases as it does adjacent to an intermittent stream. Following a period of recharge, caused either by infiltration of rain or locally byseepage from a flood wave into the adjacent banks, the water table may again rise, thus leading to increased ground-water runoff, at least temporarily.

As a flood wave passes a particular stream cross-section, the water table may rise in the adjacent stream-side deposits. The rise is caused by two phenomena. First, the stream stage, which is higher than the water table, will temporarily block ground-water runoff, thus maintaining the amount of ground water in storage. Secondly, because of the increased head in the stream, water will flow from the channel into the adjacent banks and provide another component of water added to storage. Once the flood waves begin to recede, which may occur quite rapidly, the newly added ground water begins to flow back into the channel, the rates decreasing with time. This temporary storage of water in the near vicinity of the stream channel is called bank storage. An example of bank storage is shown in Figure 2-1.

The rising and recession limbs of a hydrograph of a flood wave should provide clues concerning bank storage and streamside permeability. For example, where streamside deposits are of low permeability, such as clay or shale, the rising limb should be steep, but more gradual where the deposits are permeable. Since there would be little or no bank storage in the first case, recession curves also should be steep, but the release from bank storage in a permeable basin should reduce the slope of the recession curve.

Unfortunately, the discharge of ground water into a stream is not always as simple as has been implied from the above examples. Let us briefly examine the aquifer framework with different geologic conditions and the effect on a stream hydrograph (fig. 2-2). In the first case, the stream channel is deeply cut into shale that is overlain by sand (fig.2-2,A). Ground water flows into the stream along a series of springs and seeps issuing at the sand-shale contact. Let us assume that during a runoff event the stage rises but even at its peak, the stage remains below the top of the shale. In this case, the contribution of ground water remains constant despite the rise in stage; there is no bank storage. To separate the ground-water runoff component on the stream hydrograph, a straight line is drawn from the inflection points of the rising and falling limbs (fig. 2-2,A).

In the second example, the stream channel is cut into a deposit of sand that is underlain by shale (fig. 2-2, B). Ground water flows into the stream,

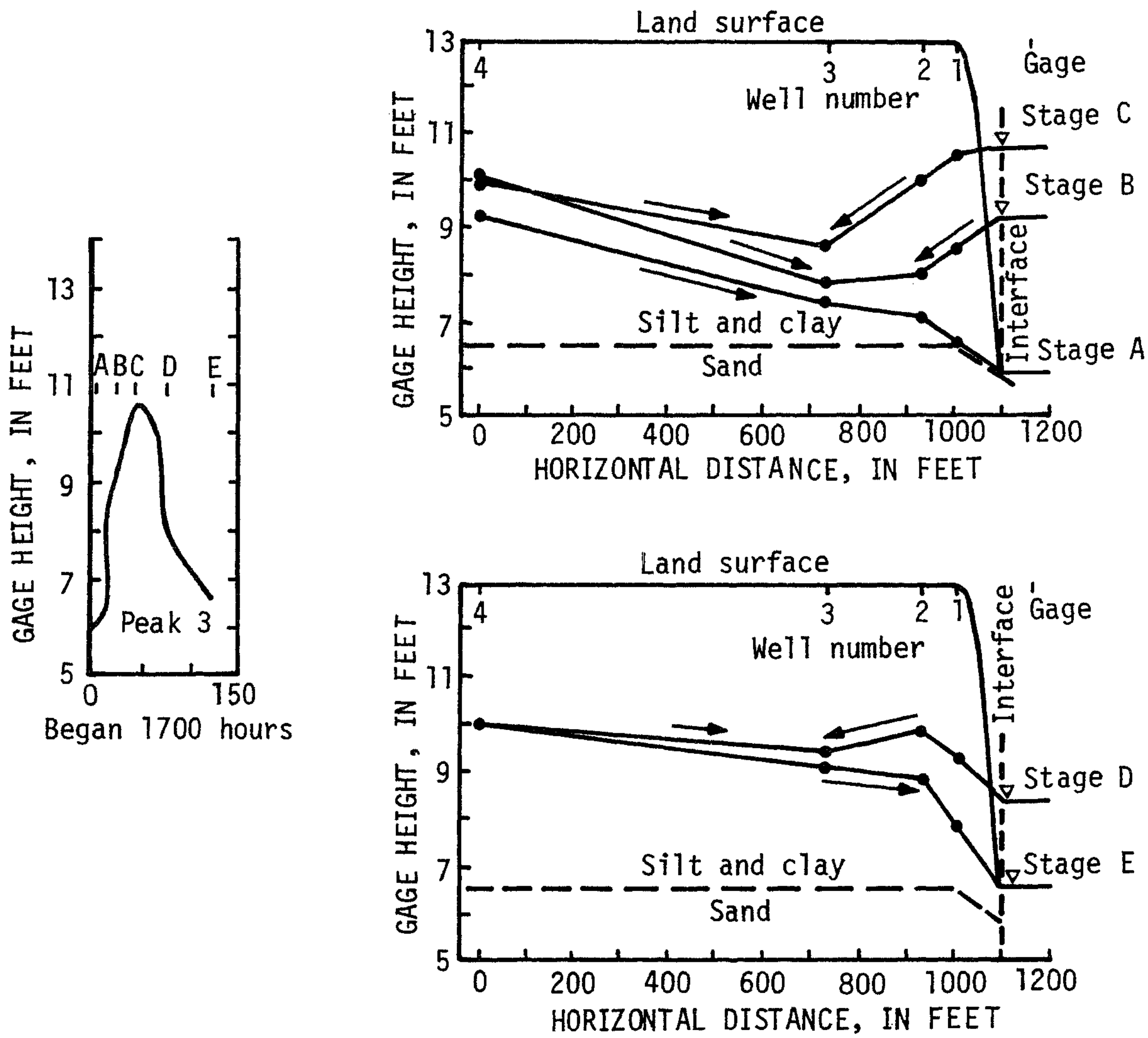
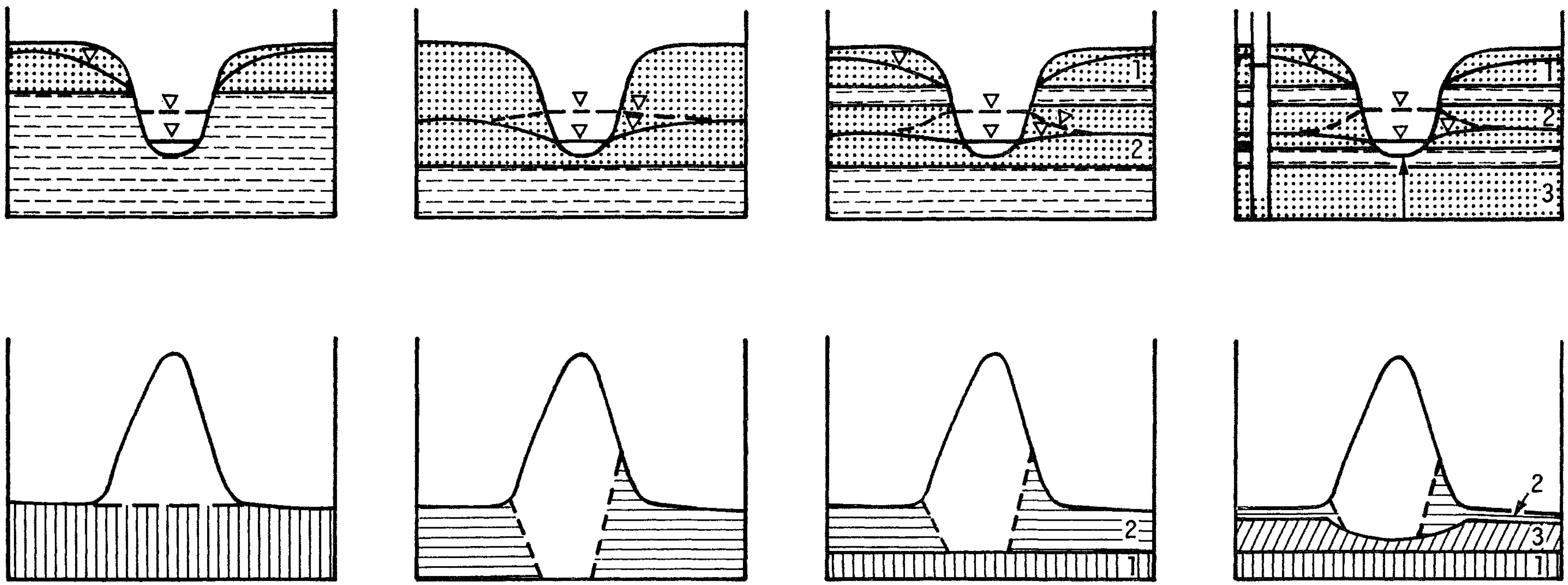



FIGURE 2-1. MOVEMENT OF WATER INTO AND OUT OF BANK STORAGE ALONG A STREAM IN INDIANA




A B C D

FIGURE 2-2. EFFECT OF GEOLOGIC FRAMEWORK ON THE SOURCES
OF GROUND-WATER RUN OFF

but as the stage rises, this flow decreases and eventually stops. Surface water then begins to flow into the ground where it is temporarily retained as bank storage. As the stage declines, ground water, now at a steep gradient, again starts to discharge into the channel and eventually provides the entire flow. This is the classic case of bank storage. Hydrograph separation is more difficult in this example and may be accomplished in the manner shown in Figure 2-2, B.

The next example is a combination of the previous two cases (fig. 2-2, C). Ground water from a perched aquifer (1) contributes a steady flow, while bank storage is gained and then released from aquifer 2. Hydrograph separation is even more difficult in this situation because of the contribution from both aquifers. The separation may be accomplished in a manner shown in Figure 2-2, C.

The final example consists of three aquifers--one perched (1), a second in direct continuity with the stream (2), while the third deeper aquifer (3) is artesian. As the stream rises, there is a decrease in the head difference between the stream and the artesian aquifer. The decrease in head difference will reduce upward leakage from the artesian aquifer, the amount depending on the thickness and vertical permeability of the confining bed and the head difference. A method of hydrograph separation in cases such as these, is shown in Figure 2-2, D.

## Hydrograph Separation

Following a runoff event, the water held as bank storage begins to discharge into the channel. In the beginning the rate of discharge from bank storage is high because of the steep water-level gradient, but as the gradient decreases so also does ground-water runoff, which may eventually cease where the aquifer is depleted. The stream hydrograph gradually tapers off into what is called a depletion curve. To a large extent, the shape of the depletion curve is controlled by the permeability of the streamside deposit, although soil moisture and evapotranspiration also play important roles. One method used to construct a depletion curve is described by Johnstone and Cross (1949).

A flood hydrograph is a composite hydrograph of surface runoff superimposed on ground-water runoff. Numerous techniques are used to separate the two components, but none are entirely satisfactory. Whatever method is employed, there is always some question as to the accuracy of the division and one can only say that in any given case, ground-water runoff is probably not less than about ** or more than about **. Keeping in mind the complexities of a runoff hydrograph brought about by variable physical, and biological parameters, and particularly the geology and topography of a basin, in the following an attempt is made to describe a few methods that are used for hydrograph separation.

On the flood hydrograph in Figure 2-3 A, the start of surface runoff occurs at point A. Using a depletion curve the original recession can be extended to B. The area below AB represents the ground-water runoff that would have occurred had there been no surface runoff. Point D represents the end of surface runoff. A depletion curve can be matched to the recession limb so that it extends from D to C. The result, ABDC, is a partial envelope that shows the upper and lower limits between which a line may reasonably be drawn to separate the two components of runoff. (This example ignores possible effects brought about by differences in the geologic framework.) This envelope forms a basis for the most commonly used separation techniques, three of which are briefly described below.

Method 1. Using a depletion curve and starting at D (fig. 2-3,B), the

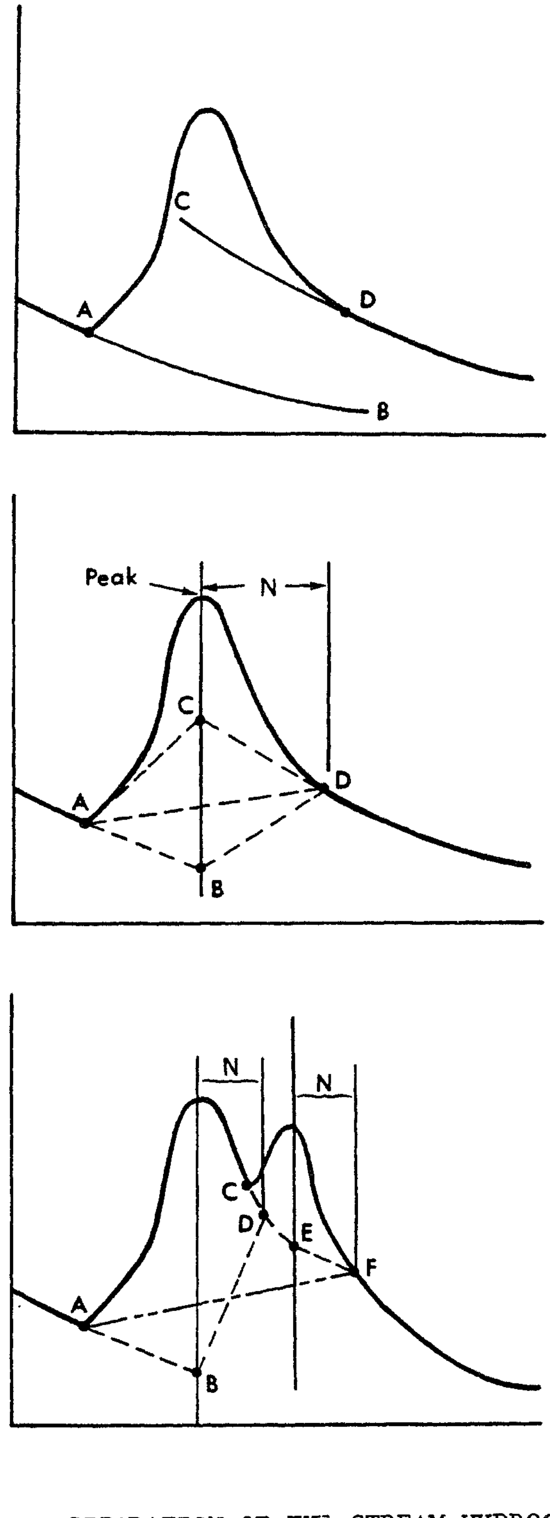



FIGURE 2-3. SEPARATION OF THE STREAM HYDROGRAPH

recession curve is extended back to a line drawn vertically through the peak of the hydrograph (C). A second line is then extended from A, the start of surface runoff, to C. The area below ACD is ground-water runoff, while that above is surface runoff. This method may be more valid where ground-water runoff is relatively large and reaches the stream quickly.

Not uncommonly, the end of surface runoff is difficult to determine, and the location of D can be established by means of the equation

$$N = A^{0.2}$$

where N = the number of days after a peak when surface runoff ceases, and A = the basin area, in square miles. The distance N is measured on the hydrograph.

Method 2. In this example (fig. 2-3 B), separation is accomplished merely by extending a straight line originating at the start of surface runoff (A), to a point on the recession curve representing the end of surface runoff (D). This method of separation is certainly the simplest and justifiable if little is known of the rate at which ground-water runoff occurs.

Method 3. The pre-runoff recession line is extended from A to a point directly under the hydrograph peak (B). From this point (B) a second line is projected to D, the end of surface runoff (fig. 2-3 B).

Commonly runoff events occur at closely spaced intervals and there is insufficient time for the recession curve to develop before runoff again increases. This complicates hydrograph separation. Two methods that can be used to determine ground-water runoff under a complex hydrograph (two storms), are shown in Figure 2-3 C and described below.

Method 1. The recession curve preceding the first runoff event is continued to its intersection with a line drawn through the first peak (A-B). The distance N is calculated and measured. The recession limb of the first event is continued to its intersection with the N-days line (C-D). Line B-D is then constructed. The first recession trend is continued to its intersection with a line drawn through the peak of the second runoff event (C-D-E). From this point (E), the line is extended N days to F.

Method 2. The easiest method is to project a straight line from A to F (fig.2-3C). Although by far the simplest, this technique is not necessarily any less accurate than Method 1, particularly if the hydrogeology of the basin is not well understood.

Regardless of the separation technique used, it should be based, insofar as possible, on knowledge of the hydrogeology of the basin, keeping in mind the effect of the geologic framework on the hydrograph.

## Flow-Duration Curves

As pointed out by Cross and Hedges (1959), flow-duration curves are widely used and there is considerable technical literature on the subject. From a hydrogeologic viewpoint they are most useful for comparing the flow characteristics of different streams because the shape of the curve is an index of the natural storage within a basin. When plotted on logarithmic probability paper, the more nearly horizontal the curve, the greater is the effect of ground-water storage.

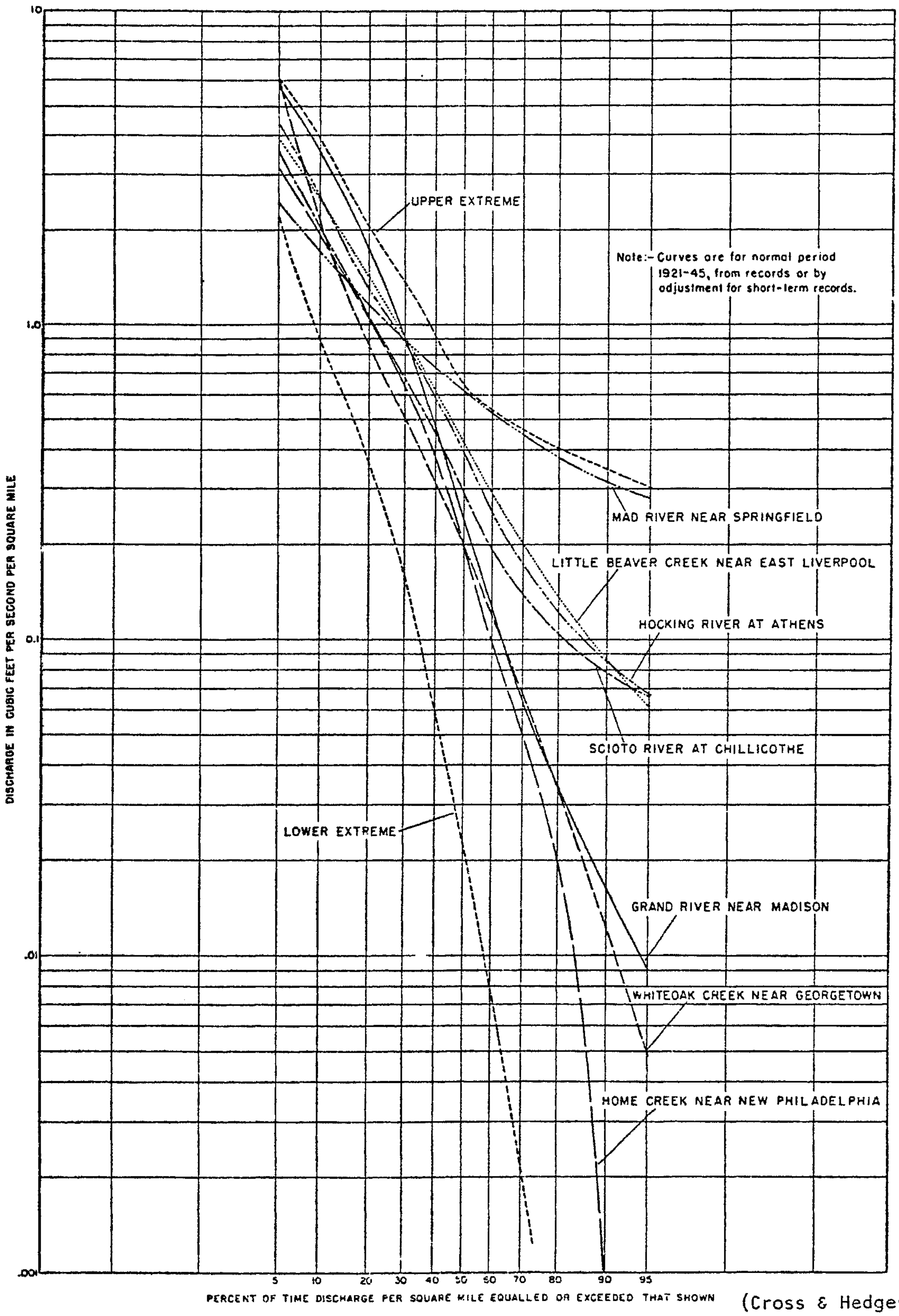
> During dry weather, the flow of streams is almost entirely from ground-water sources. The lower ends of duration curves therefore indicate in a general way the characteristics of the shallow ground-water bodies in the drainage basin above the gaging station. Duration curves thus are useful guides in locating possible sources of ground water. (Cross and Hedges, 1959, p. 5).

Despite the fact that changes in the drainage basin, such as regulation, diversion and variable discharges of effluent, will alter the shape of the duration curve, with judgment and comparison with unaffected nearby streams, even records of these streams can provide useful approximation of the hydrogeologic system.

A flow-duration curve shows the frequency of occurrence of various rates of flow. It is a cumulative frequency curve prepared by arranging all discharges of record in order of magnitude and subdividing them according to the percentages of time during which specific flows are equalled or exceeded; all chronologic order or sequence is lost (Cross and Hedges, 1959). Flow-duration curves may be plotted on either probability or semilogarithmic paper.

Several flow-duration curves for Ohio streams are shown in Figure 2-4. During low-flow conditions (the flow equalled or exceeded 90 percent of the time) the curves for several of the streams, such as the Mad, Hocking and Scioto Rivers, and Little Beaver Creek trend toward the horizontal, while Grand River, White Oak and Home Creeks all remain very steep.

Mad River flows through a broad valley filled with very permeable sand and gravel. The basin has a large ground-water storage capacity and, consequently, the river maintains a high sustained flow. The Hocking River valley also contains outwash in and along its floodplain, particularly in the upper reaches, which provides a substantial amount of ground-water runoff. Above Columbus, the Scioto River crosses glacial till and thin layers of limestone that crop out along the stream channel; ground-water runoff in this reach is relatively small. Immediately south of Columbus, however, the Scioto River valley is filled with coarse outwash and during low flow the discharge increases substantially at succeeding downstream gages. The reason that Mad River has a higher low-flow index than the Scioto River is because the former receives ground-water runoff throughout its entire length, while ground-water runoff to the Scioto River increases significantly only in the



(Cross & Hedges, 1959)

FIGURE 2-4. FLOW-DURATION CURVES FOR SELECTED OHIO STREAMS, SHOWING SPREAD OF CURVES FOR ALL NON-REGULATED GAGING STATIONS area of outwash south of Columbus.

White Oak and Home Creeks originate in bedrock areas where relatively thin alternating layers of shale and limestone are covered by till (White Oak Creek) or sandstone, shale, and limestone crop out along hillsides (Home Creek). The low permeability of the strata and the greater relief in these basins preclude the storage of large amounts of ground water and, consequently, the low flows characteristic of these streams are far less than those filled or partly filled with outwash.

## Flow Ratios

Walton (1971) reported that grain-size frequency-distribution curves are somewhat analogous to flow-duration curves in that their shapes are indicative of water-yielding properties of rocks. He pointed out that a measure of the degree to which all of the grains approach one size (the slope of the grain-size frequency distribution curve) is the sorting. One parameter of sorting is obtained by the ratio $(D_{25}/D_{75})^{\frac{1}{2}}$, where $D_{25}$ is the grain size that has 25 percent larger and 75 percent smaller, and $D_{75}$ is the grain size where 75 percent is larger and 25 percent is smaller. Walton modified this equation by replacing the 25 and 75 percent grain-size diameters with the 25 and 75 percent flow $(Q_{25}/Q_{75})^{\frac{1}{2}}$. In this case a low ratio is indicative of a permeable basin that has a large storage capacity. This technique provides another simple and quick method for hydrologic evaluations of drainage basins.

The $Q_{25}$ and $Q_{75}$ data are easily obtainable from flow-duration curves. Using the data from Figure 2-4, it is evident that Mad River has a flow ratio of 1.59 and the Scioto River a ratio of 2.64, while Home Creek, typifying a basin of low permeability, has the highest ratio of 5.09.

## Seepage or Dry-Weather Measurements

Seepage or dry-weather measurements consist of flow determinations made at several locations along a stream during a short time interval when there is no surface runoff. Many investigators prefer to initiate seepage runs during the stream's 90 percent flow duration, that is, when the flow is so low that it is equalled or exceeded 90 percent of the time.

It is not always possible to conduct an actual seepage survey due to time, manpower, or financial constraints. In these cases, the flow-duration curve may serve as a valuable substitute.

Seepage measurements permit a quick evaluation of ground-water runoff--how much there is and where it originates--and provides clues to the geology of the basin as well. The flow of some streams increases substantially within a short distance. Under natural conditions the increase is most likely related to increased ground-water runoff originating in deposits or zones of high permeability in or adjacent to the stream channel. These gaining reaches may consist of deposits of sand and gravel, fracture zones, solution openings in limestone or merely by local facies changes. In addition, ground water may also discharge through a series of springs or seeps along valley walls or in the stream channel.

In areas where the geology and ground-water systems are not well known, streamflow data can provide a means of testing estimates of the ground-water system. If the streamflow data do not conform to the estimates, then the geology must be more closely examined (LaSala, 1968). For example, the northwest corner of Ohio is crossed by the Wabash and Fort Wayne moraines between which lies the St. Joseph River. As indicated by the Glacial Map of Ohio (Goldthwait and others, 1961), the St. Joseph Basin consists mainly of till. However, low-flow seepage measurements show that the discharge of the river increases more than 14 cfs along its reach in Ohio, indicating that the basin contains a considerable amount of outwash, which in this case is covered by a relatively thin layer of till.

The mainstem of the Auglaize River in northwestern Ohio rises from a mass of outwash that lies along the front of the Wabash moraine. The southwest-flowing river breaches the moraine near Wapakoneta and then flows generally north to its confluence with the Maumee River at Defiance. A gaging station is near Ft. Jennings in a till plain area and slightly above a reservoir on the Auglaize. This gage measures the flow resulting as an end product of all causitive hydrologic factors upbasin (ground-water runoff, surface runoff, slope, precipitation, use patterns, etc.)--it shows merely inflow to the reservoir. Low-flow measurements, however, indicate that nearly all of the baseflow is derived from outwash along the distal side of the Wabash moraine; there is no gain across the wide till plain downstream.

A number of discharge measurements have been made in the Scioto River Basin. The flow measurements in themselves are important because they show the actual discharge, in millions of gallons per day per square mile, in this case, at about the 90 percent flow (fig. 2-5). Notice that the discharge at succeeding downstream sites on the Scioto River is greater than the flow immediately upstream. This shows that the river is gaining and that water is being added to it by ground-water runoff originating largely from the adjacent outwash deposits.

A particularly useful method for evaluating streamflow consists of relating the discharge to the size of the drainage basin (cfs or mgd/sq. mi. of drainage basin). A cursory examination of Figure 2-5 shows that it is convenient (and totally arbitrary) to separate the flow into three distinctive units, Unit 1 falls in the range of .010 to .020 mgd/mi. sq., Unit 2 includes .021 to .035

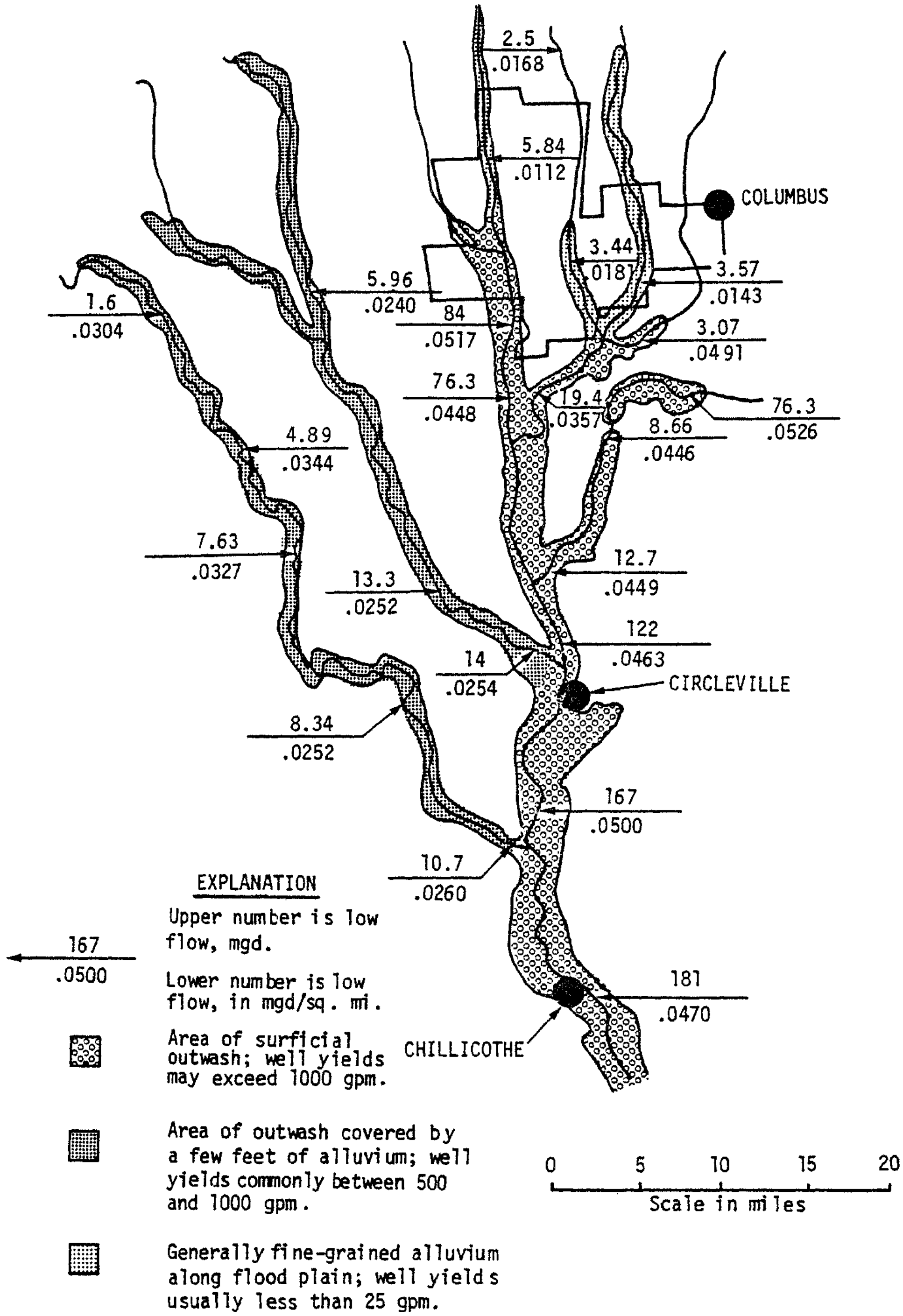



FIGURE 2-5. DISCHARGE IN THE SCIOTO RIVER BASIN IS STRONGLY INFLUENCED BY THE LOCAL GEOLOGIC CONDITIONS

mgd/mi. sq., and Unit 3 is .036 to .050 mgd/mi. sq. The Olentangy River and Alum and Big Walnut Creeks fall into Unit 1, Big Darby and Deer Creeks into Unit 2, and the Scioto River, Walnut Creek, and the lower part of Big Walnut Creek into Unit 3. Even though the latter watercourses fall into Unit 3, the actual discharge ranges widely, from 3.07 to 181 mgd.

Logs of wells drilled along the streams of Unit 1 show a preponderance of fine-grained material that contains only a few layers of sand and gravel, and wells generally yield less than 25 gpm. Logs of wells and test holes along Big Darby and Deer Creek, however, indicate that several feet of sand and gravel underlie fine-grained alluvial material, which ranges in thickness from 5 to more than 25 feet. Adequately designed and constructed wells that tap these buried outwash deposits produce as much as 500 gpm. Glacial outwash, much of it coarse grained, forms an extensive deposit through which Unit 3 streams and rivers flow. The outwash extends from the surface to depths that in places exceed 200 feet. Industrial wells constructed in these deposits, most of which rely on induced infiltration, can produce more than 1000 gpm. Thus, it is evident that by combining seepage data and well yields with a geologic map, it is possible to develop another map that may indicate potential well yields. The potential ground-water yield map relies heavily on streamflow measurement as well as judgment, but nonetheless provides, with some geologic data, a good first cut approximation of ground-water availability.

## Water Quality Duration Curves

A water quality-duration curve is similar to its counterpart, the flow-duration curve, and is prepared in the same manner except that the stream's concentration of selected chemical constituents replaces discharge data. The quality duration curve can be used for three purposes. First, it shows the streams range in concentration of any substance examined. This is useful for water-treatment plant designs and dilution studies. Secondly, it can provide a good approximation of the chemical quality of ground water in the zone of active circulation. Finally, in certain instances it can be used to indicate areas of contaminated surface water.

As discussed previously, during a stream's period of low flow, all of the water in the channel consists of ground-water runoff, unless the stream receives effluent. Therefore, within limits, at these times a stream's quality closely approximates the chemical quality of shallow ground water in the basin. (This assumption is not entirely correct, however, because some chemical changes may occur at or near the ground water - surface water interface).

Although more work needs to be done along these lines, it appears that a stream's 10 percent concentration, the concentration equalled or exceeded 10 percent of the time, provides a reasonable estimate of the chemical quality of shallow ground water. It is imperative, however, that values obtained from quality-duration curves be compared with analyses of well water. A quality-duration curve for Paint Creek based on data from 1967 is shown in Figure 2-6. This is a typical curve for a stream that is uncontaminated with respect to chloride. The 10 percent concentration is about 21 mg/l; shallow well data indicate that the natural concentration of chloride in the basin generally ranges from 3 to about 28 mg/l. Thus the estimate of ground-water quality based on the duration curve is in close agreement with actual well data.

Oftentimes it is possible to determine if a stream is contaminated by means of quality-duration curves, although the method is somewhat subjective and based on some prior knowledge. A quality-duration curve of sulfate in Raccoon Creek, a stream contaminated by drainage from coal mines, is shown in Figure 2-7. In this case the 10 percent concentration of sulfate (250 mg/l) is far greater than the background content, but the concentration of hardness is

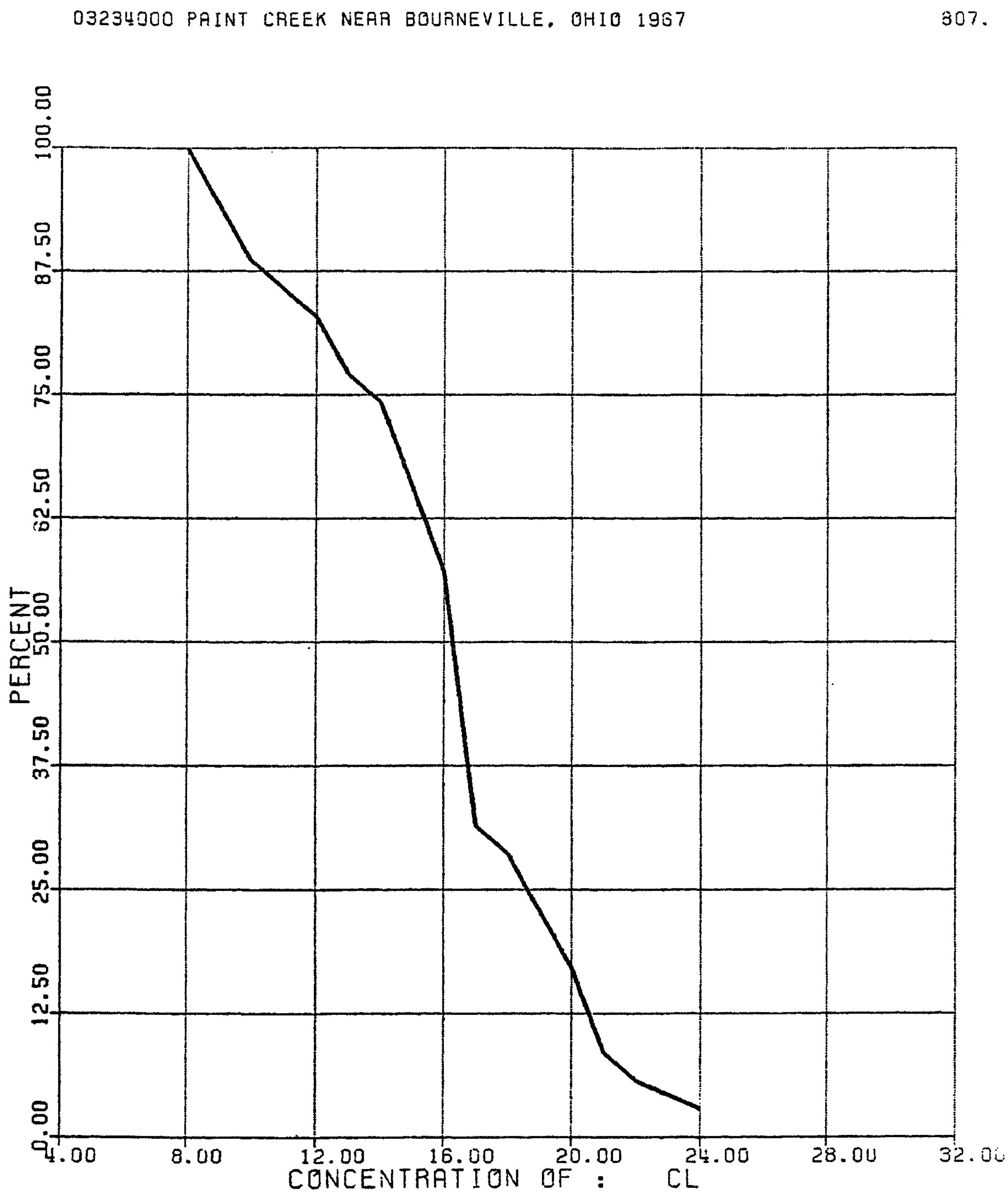



FIGURE 2-6. CHLORIDE DURATION CURVE OF PAINT CREEK IN 1967

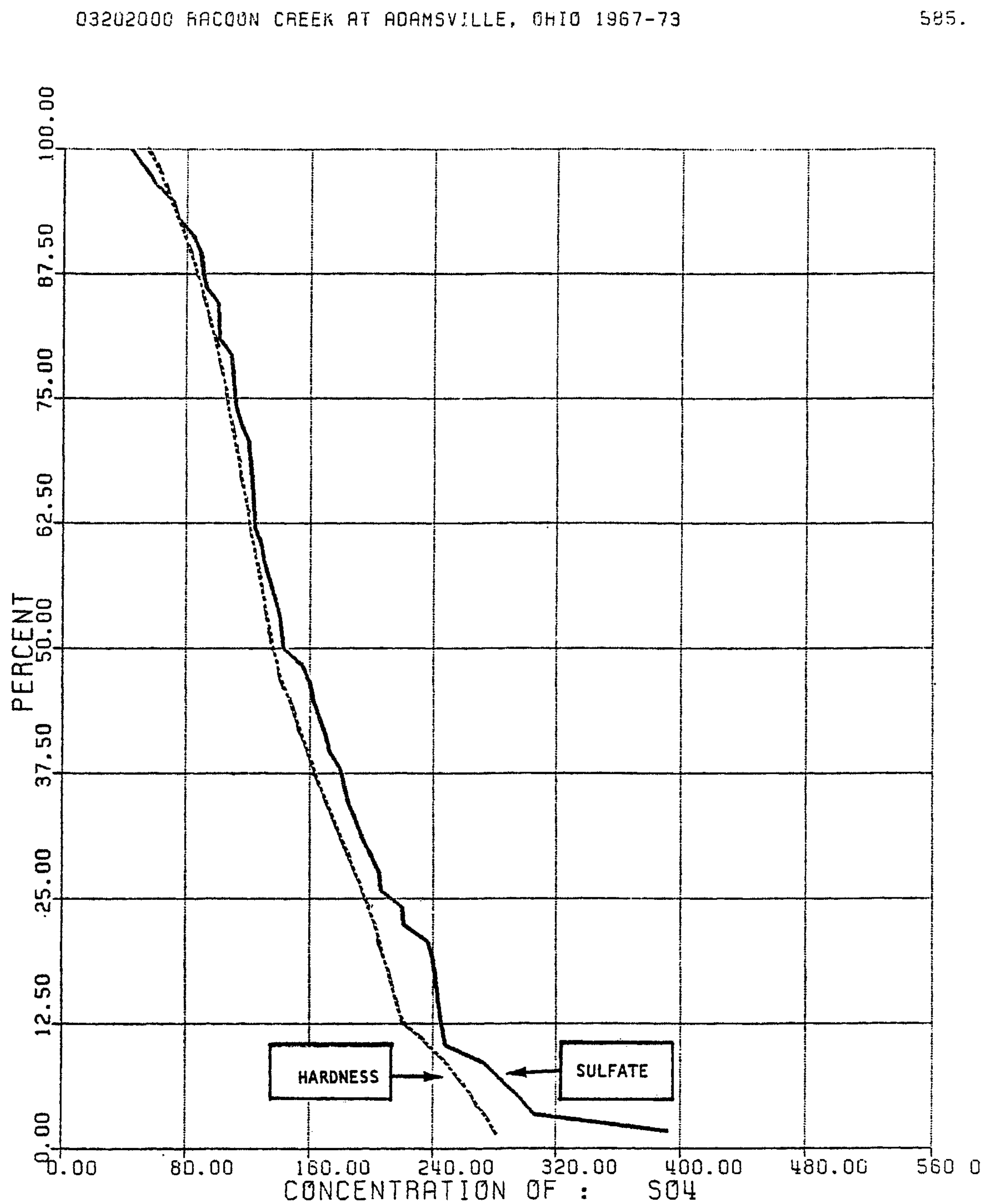



FIGURE 2-7. HARDNESS AND SULFATE DURATION CURVES FOR RACOON CREEK

within expected limits (220 mg/l). Therefore, despite the fact that a stream is contaminated with respect to one or more constituents, the contamination does not completely invalidate the usefulness of curves depicting other constituents.

## Chapter 3

## COMPUTER PROGRAM DEVELOPMENT

### Model Development

The computer programs developed for this study were based on the philosophy that no single hydrograph separation technique is suitable for all situations. Therefore, three different techniques were formulated rather than a single standardized separation method.

Hydrograph separation by manual methods is generally limited by time constraints to a single technique, but with the digital computer, additional separation methods require only microseconds. Those that utilize the shape of the hydrograph can be used without additional data.

The main program used in this study is written in FORTRAN IV for use on an IBM 370/168. It directs different separation techniques and output modes, which are subroutines to the main program.

### Main Program

The purpose of the main program is to read station data, check the validity of the input array, and direct various different forms of output. One form of the program uses a "command language" so that it can be used in classroom exercises or as a "canned program" by persons not familiar with FORTRAN.

The program is designed to handle data input arrays consisting of discharge data, in sequential order, for 365 days (October 1 to September 30). Discharge data are stored and handled as a single dimensioned variable with 365 individual elements. The specific program can handle a large majority of the data traditionally obtained from gaging stations. The program was not developed to accept data arrays during leap year (366 days) or periods that do not correspond to water years because of the increased cost of each program cycle.

Data can be input as cards or a tape record. Format for the card input consists of a title card with (1) a year identifier (columns 1-2), (2) a U.S.G.S. station number (columns 3-10), (3) a station name with no more than 54 literal characters (columns 11-65), (4) the drainage area with a punched decimal (columns 68-75) and (5) 365 in columns 78-80. The next 37 cards are discharge data, 10 days to a card (8 columns for each day) with a decimal or right justified within the field. Missing discharge data are entered as a -1. Tape input is similar, but the information for each station is compressed to 3012 bytes.

During the data verification section of the program, syntax is checked and discharge scanned to see if it falls within the general range observed in Ohio ( 100 cfs/sq. mi.). Also, missing data points are counted and reported on the print-out.

The N-interval, which must be sent to the separation subroutines, is calculated by the program. This interval is based on the empirical relationship of $N = A^{0.2}$, where A is the size of the drainage area, in square miles, and N is the number of days after which surface runoff ceases. The interval used in this program is approximately 2N, since the interval is adjusted to the nearest odd integer in the range of 3 to 11.

Subroutines

Each subroutine is summoned by a different call statement. FXINTR, a fixed interval subroutine, SLINTR, the sliding interval subroutine and LOCMIN, the local minima subroutine, all are separation techniques that should be followed by a call to an output technique. One of the more important output techniques is STATGW, which consists of a printout of total discharge of the water year, the mean, minimum, maximum and total discharge per year per basin area, the total ground-water runoff for the year, and the annual ground-water runoff per basin area. Furthermore, percent of total discharge due to ground-water runoff and recharge rates are also calculated.

Another output subroutine is MONTHS. This subroutine calculates the total discharge, the ground-water runoff, percent ground-water runoff and recharge rates for each month. VERSAP is a hydrograph-plotting subroutine that plots the annual hydrograph and ground-water separation curve on the Versatec printer plotter, HYDGPH prints a hydrograph on the line printer, FLWDUR prints a flow-duration curve on the line printer, whereas the VFWDUR outputs a log-probability plot of a flow-duration curve on the Versatec printer/plotter.

The Versatec flow-duration subroutine is more involved than the line printer subroutine because the former accepts station data that have been previously sorted so that different years, as many as three, may be plotted on the same grid. It works in the following manner. The main program reads the station name and number and checks whether or not it is a new station number. If it is, then a subroutine is called that plots the grid and then calculates and plots the first flow-duration curve. If it is not the first time the station number has appeared, then the grid is not replotted, but rather only the new flow-duration curve for that particular year is plotted on the same graph. In this way, previously sorted stations from one year to another can be compared. For example, in this study, the years 1963, 1967 and 1973 were chosen because they represented years of low, normal and high precipitation. The flow-duration curves for each station show whether or not this particular stream experienced similar trends. Throughout most of Ohio, flow-duration curves for 1963 had the lowest flows and 1973 the highest flows. In some basins, however, an opposite trend was evident indicating that precipitation in some basins did not conform to the state average, or that water withdrawal within the basin may have altered the high or low flows, or that control structures had been put into operation sometime during the period of 1963-1973.

Because the most important aspects of the flow-separation program are the calculation subroutines, these will be discussed in more detail than the input or output routines. The significant point in all of these programs is the form of the input data stream.

A hydrograph constructed from instantaneous discharge measurements will differ from a hydrograph plotted from daily mean discharge, particularly during periods of flood flow because the instantaneous discharge will generally be higher. Periods of recession will correspond closely for both cases except for very flashy streams. Most Ohio streams have a range of recession curves determined by season and basin characteristics. Almost all of these streams exhibit recession curves that indicate that daily mean flow values closely approximate the instantaneous data hydrograph.

The main difference between hydrographs based on instantaneous versus daily mean discharge data are, therefore, most significant at high flows, where this study focuses little attention. Because of complications mentioned earlier, the ground-water component of total flow during floods is speculative. Also, for most streams in Ohio, ground-water runoff is a significant part of the flow when expressed as percentage. All the calculation techniques are based on discrete data elements rather than a continuum of values, or a continuous function. The explanations will use examples that appear to be continuous, but it must be remembered that the data array is in discrete daily mean discharge values.

In the following example, Deer Creek at Mount Sterling during water year 1967 is used. The drainage area contains 228 sq. mi., thus N is 2.96 days and the separation interval is 5 days. The basin is mantled by glacial till and relief is low.

The subroutine that uses the fixed interval (FXINTR) technique separates the hydrograph by moving, vertically and horizontally, a bar of 2N width upward from a base line until a part of the bar intersects the hydrograph at one point. All elements of that line are then assigned that minimum discharge value. An example of this method is illustrated in Figure 3-1. Therefore, the lowest discharge value within an interval is determined and all array elements in the interval are assigned that value. This happens for K = 365/2N thus dividing the year into K intervals and the operation is then done for each interval.

The subroutine that uses the sliding interval (SLINTR) technique is similar to moving a bar, 2N wide, upward from a base line to a point where it intersects the hydrograph at one point. The discharge value of the hydrograph is then assigned to the median element of the interval. The bar then slides over to the next day and again moves up until the hydrograph is encountered (fig. 3-2). Actually, the value of the elements on both sides of the point being considered for one half of the interval minus one are scanned and the element with lowest value is assigned as the ground-water component of the point being considered. This process is carried out for each element of the discharge array.

The subroutine that uses the local minimum (LOCMIN) technique is similar to the low point method that is accomplished manually (fig. 3-3). In this technique, the discharge array is scanned, element by element, to determine if it is the lowest value in the interval (½ the interval minus one on either side of the element.) If it is, then it is a local minimum and is connected by straight lines to adjacent local minimums. The discharge values are calculated between each local minimum by using the slope of the line at each discrete discharge element.

A comparison of sections of a hydrograph separated by each of the three

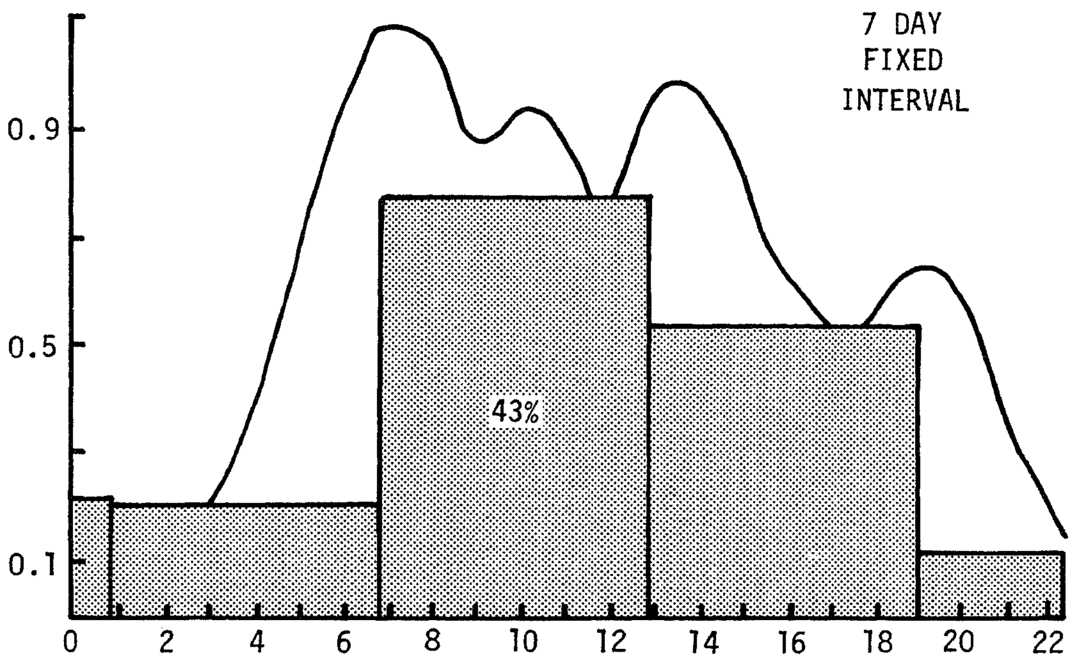



FIGURE 3-1. HYDROGRAPH SEPARATION BY THE
FIXED INTERVAL (FXINTR) METHOD

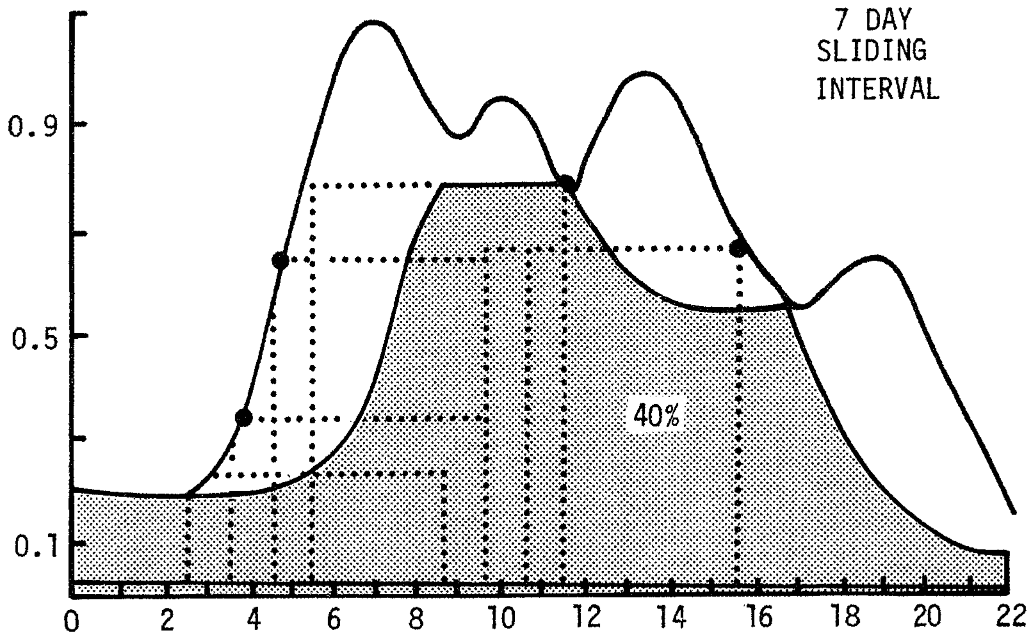



FIGURE 3-2. HYDROGRAPH SEPARATION BY THE SLIDING INTERVAL (SLINTR) METHOD

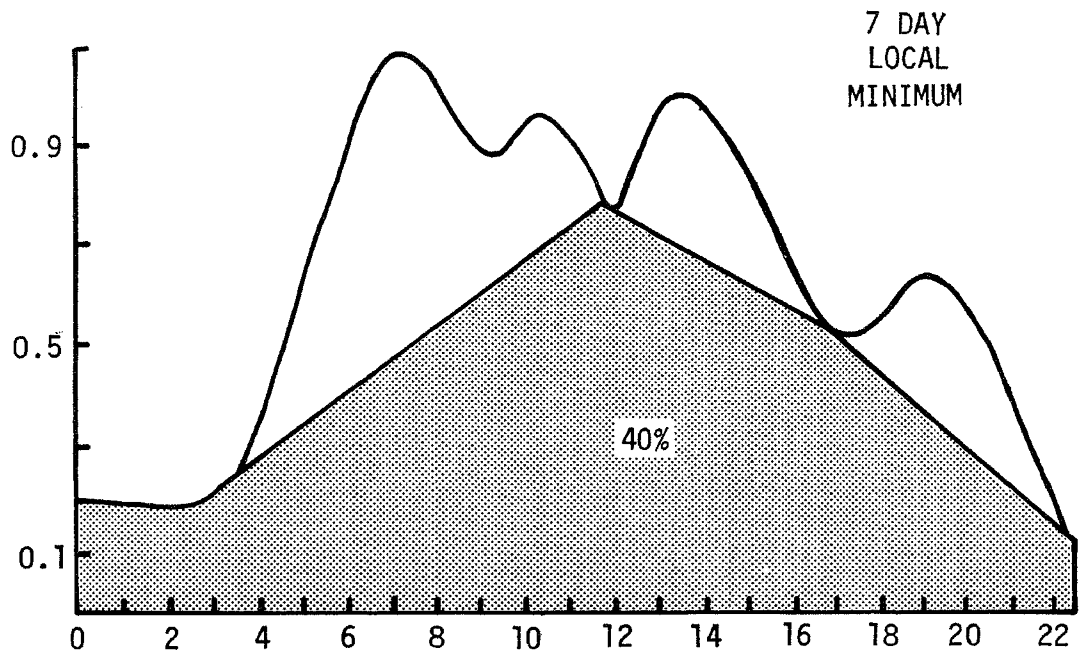



FIGURE 3-3. HYDROGRAPH SEPARATION BY THE LOCAL MINIMUM (LOCMIN) METHOD

methods is illustrated in Figure 3-4.

Even though most of the illustrative output modes use a logarithmic scale, the arithmetic scale hydrograph is numerically the same although it looks quite different (fig. 3-5). Because low-flow conditions are an important consideration in this study, the logarithmic scale has been used to allow a more accurate visual interpretation of these conditions. The arithmetic scale hydrograph is included in the Calcomp plotting program that uses input as card decks from the main flow-separation program.

As pointed out earlier, output from the main flow-separation program can take many forms. As each subroutine's command card is read, the command is printed by the line printer to indicate that the operation called has been invoked, or has caused the program to flush to the next station. If the operation was invoked, but some warning is called, such as a number of days with no record, or no flow, a warning is printed directly below the command card image. If a command card is incorrect or some defect in the data has been encountered, the program will flush to the next "read" card. A message referring to the approximate cause of the error will appear after the image of the incorrect card or operation. After the flush, each card image will be printed on the line printer, but no operation will be invoked until a "read" card is encountered.

An example of some line-printer output is shown in Figure 3-6. The data deck used to produce this example is shown in Figure 3-7. Line-printer plots of hydrographs and flow-duration curves are useful for a first look at station data. The line printer output modes can be used at any IBM 370 FORTRAN compiler without major modification. The reread capability is written in ASSEMBLER but the program can be easily modified so that it no longer requires this language by using FORTRAN rewind (at considerable expense) or modifying the

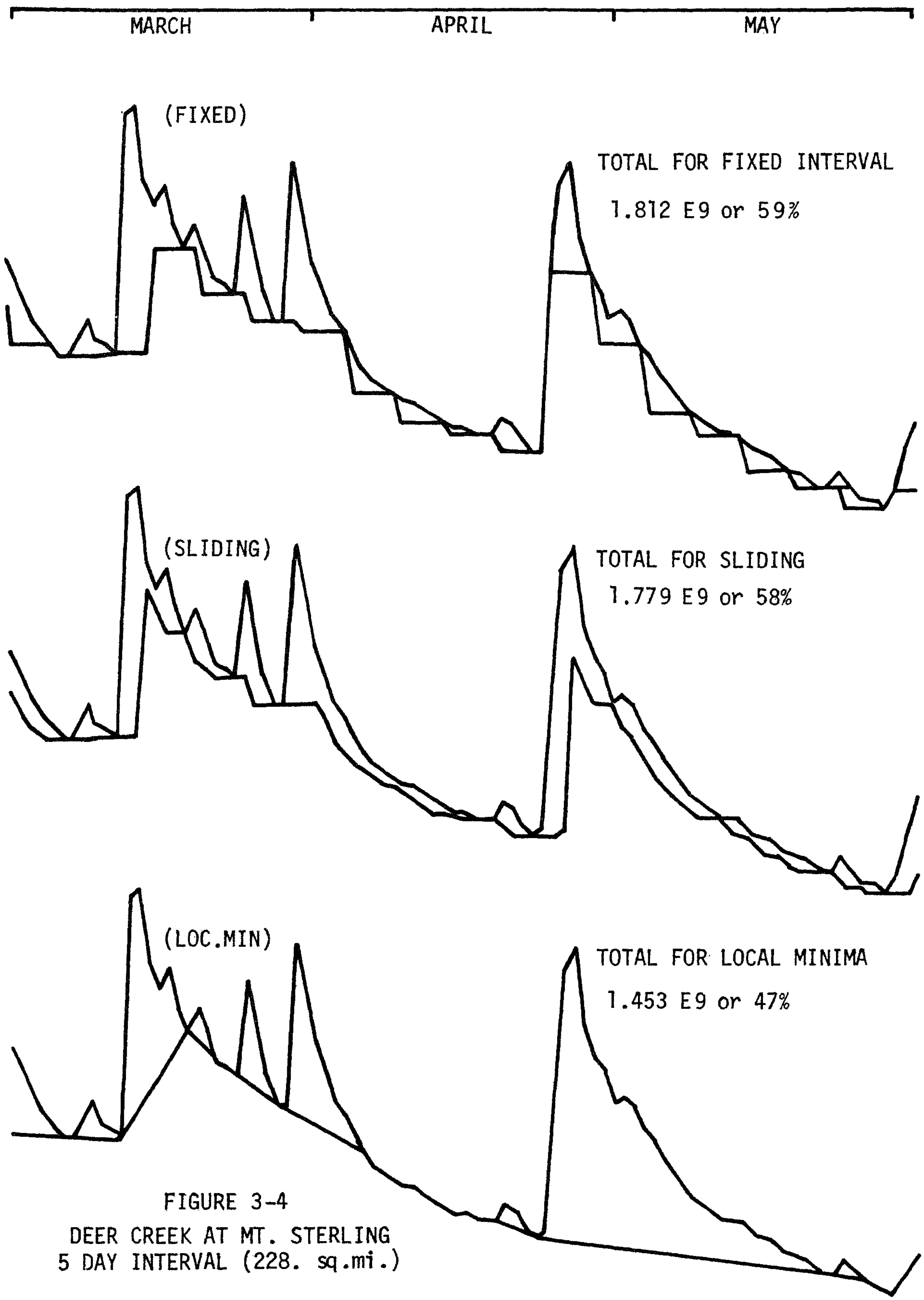
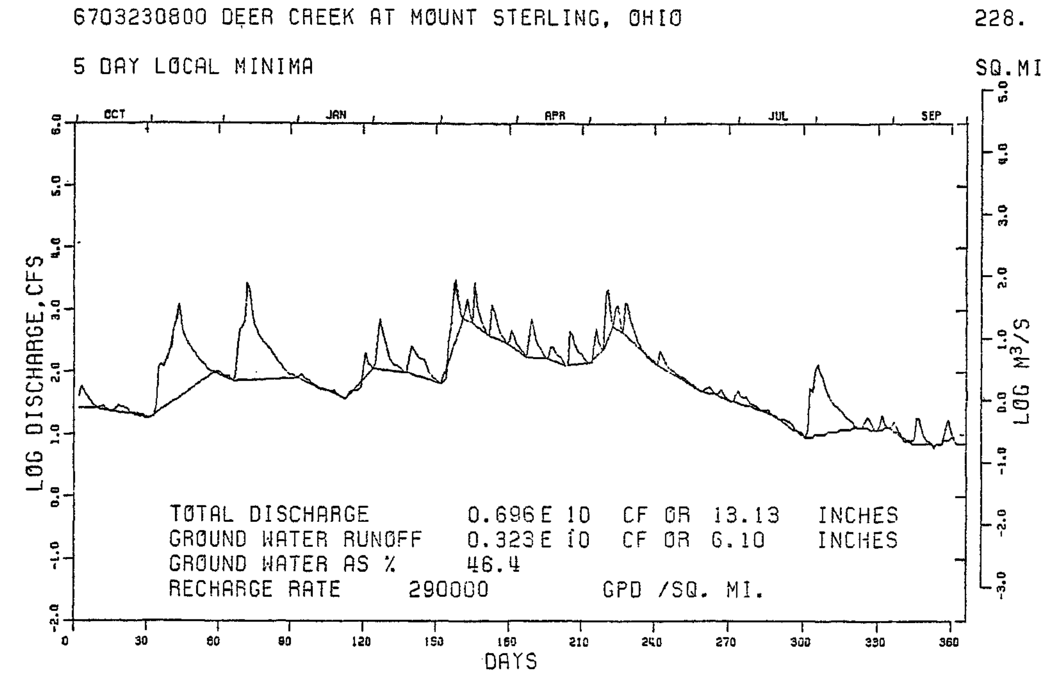



FIGURE 3-4
DEER CREEK AT MT. STERLING
5 DAY INTERVAL (228. sq.mi.)



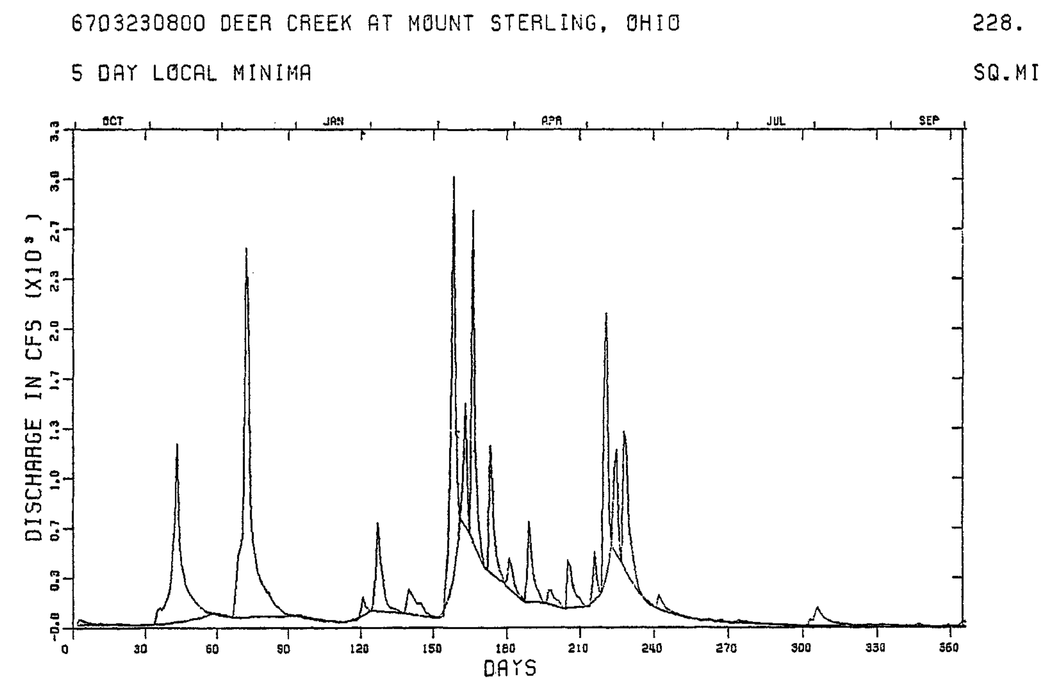




FIGURE 3-5. DEER CREEK HYDROGRAPHS PLOTTED ON LOGARITHMIC (UPPER) AND ARITHMETIC (LOWER) SCALES

READ DISCHARGE DATA FROM CARDS(10 TO A CARD,8 COLUMNS EACH.)

```
**********************************************************
 7503230800 DEER CREEK AT MOUNT STERLING, OHIO                228.00  365
**********************************************************
```

AND CALCULATE BY THE FIXED INTERVAL METHOD

FIXED INTERVAL, INTERVAL= 5 DAYS

AND PRINT OUT SOME SUMMARY STATISTICS FOR THE YEAR

| | | | |
|---|---|---|---|
| TOTAL DISCHARGE FOR THE WATER YEAR | 9.335E+09 CF | OR | 17.62 INCHES |
| MINIMUM DISCHARGE | 11.00 CFS | | |
| MEAN DISCHARGE | 296.02 CFS | | |
| MAXIMUM DISCHARGE | 9080.00 CFS | | |
| TOTAL DISCHARGE/YR/BASIN AREA | 4.094E+07 CF/SQ.MI | | |
| THE TOTAL GROUND WATER DISCHARGE FOR A YEAR | 5.225E+09 CF | OR | 9.86 INCHES |
| TOTAL GROUND WATER DISCHARGE/YR/BASIN AREA | 2.291E+07 CF /SQ.MI. | | |
| % OF TOTAL DISCHARGE DUE TO GROUND WATER RUNOFF | 55.97 | | |

THE RECHARGE RATE = 469000. CPD/SQ.MI.

* * * * * * * * * * * * * * * * * *

AND PRINT OUT MONTH-BY-MONTH SUMMARY STATISTICS

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL Q(CF) | 1.42E+08 | 3.48E+08 | 1.22E+09 | 1.54E+09 | 2.20E+09 | 1.95E+09 | 7.90E+08 | 3.25E+08 | 5.23E+08 | 1.58E+08 | 5.88E+07 | 8.16E+07 |
| TOTAL Q(IN) | 0.269 | 0.657 | 2.296 | 2.912 | 4.156 | 3.679 | 1.491 | 0.614 | 0.987 | 0.299 | 0.111 | 0.154 |
| GW (CF ) | 1.17E+08 | 2.53E+08 | 7.30E+08 | 9.38E+08 | 9.24E+08 | 9.78E+08 | 5.61E+08 | 2.73E+08 | 2.49E+08 | 9.87E+07 | 4.64E+07 | 5.57E+07 |
| GW (IN ) | 0.222 | 0.478 | 1.379 | 1.770 | 1.745 | 1.846 | 1.059 | 0.516 | 0.469 | 0.186 | 0.088 | 0.105 |
| % AS G W | 82.46 | 72.77 | 60.05 | 60.80 | 41.99 | 50.19 | 71.03 | 84.05 | 47.54 | 62.30 | 78.97 | 68.25 |
| RR CPD/MI2 | 124000. | 276000. | 772000. | 992000. | 1083000. | 1035000. | 613000. | 289000. | 271000. | 104000. | 49000. | 60000. |

* * * * * * * * * * * * * * * * * * * * * * * * * *

AND ON VERSATEC PLOT A HYDROGRAPH WITH SEPARATION

AND PRINT OUT A HYDROGRAPH ON THE LINE PRINTER

7503230800 DEER CREEK AT MOUNT STERLING, OHIO    228.00 SQ.MI

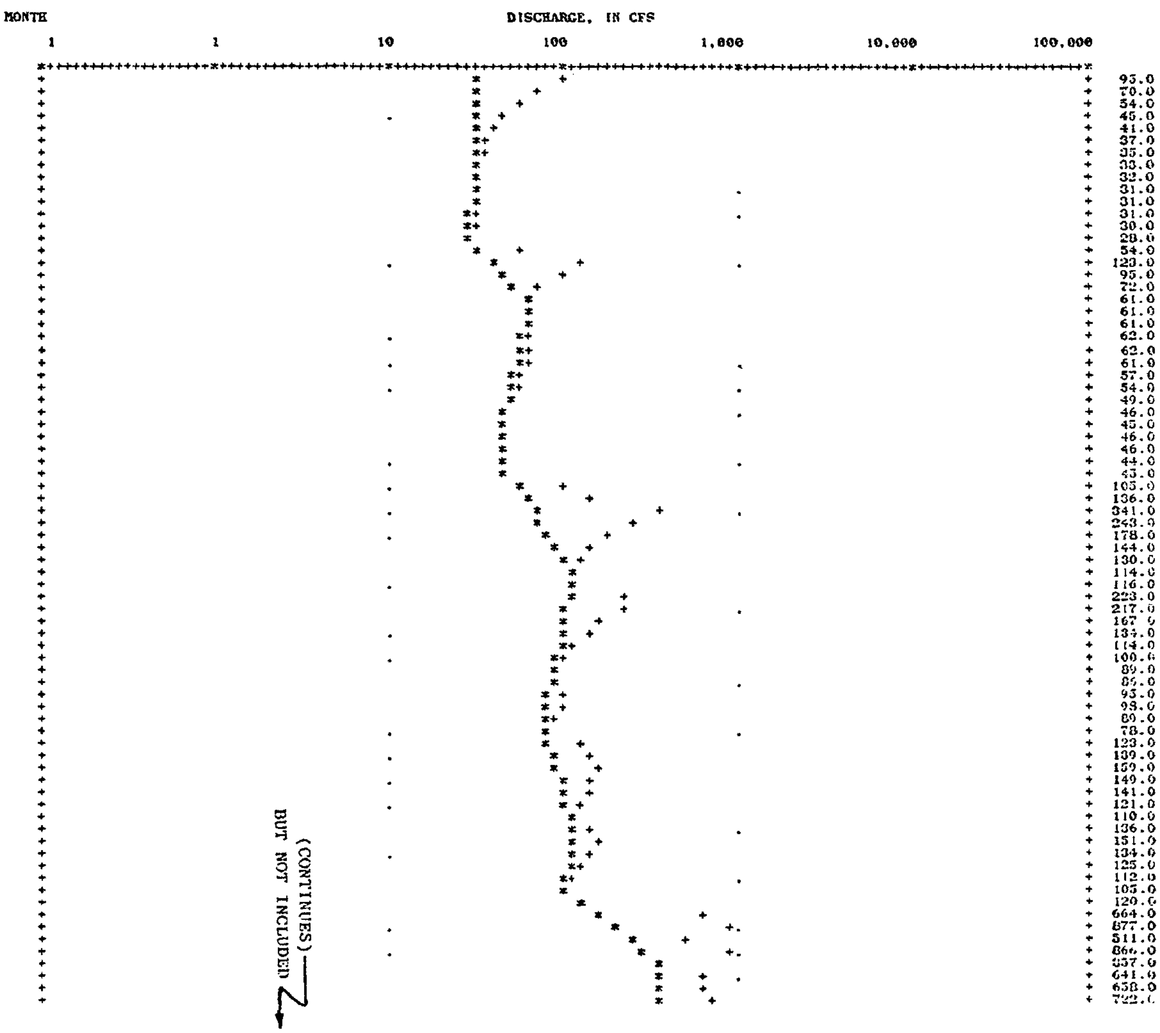



FIGURE 3-6. DEER CREEK HYDROGRAPHS (PARTIAL)
PRODUCED BY LINE-PRINTER

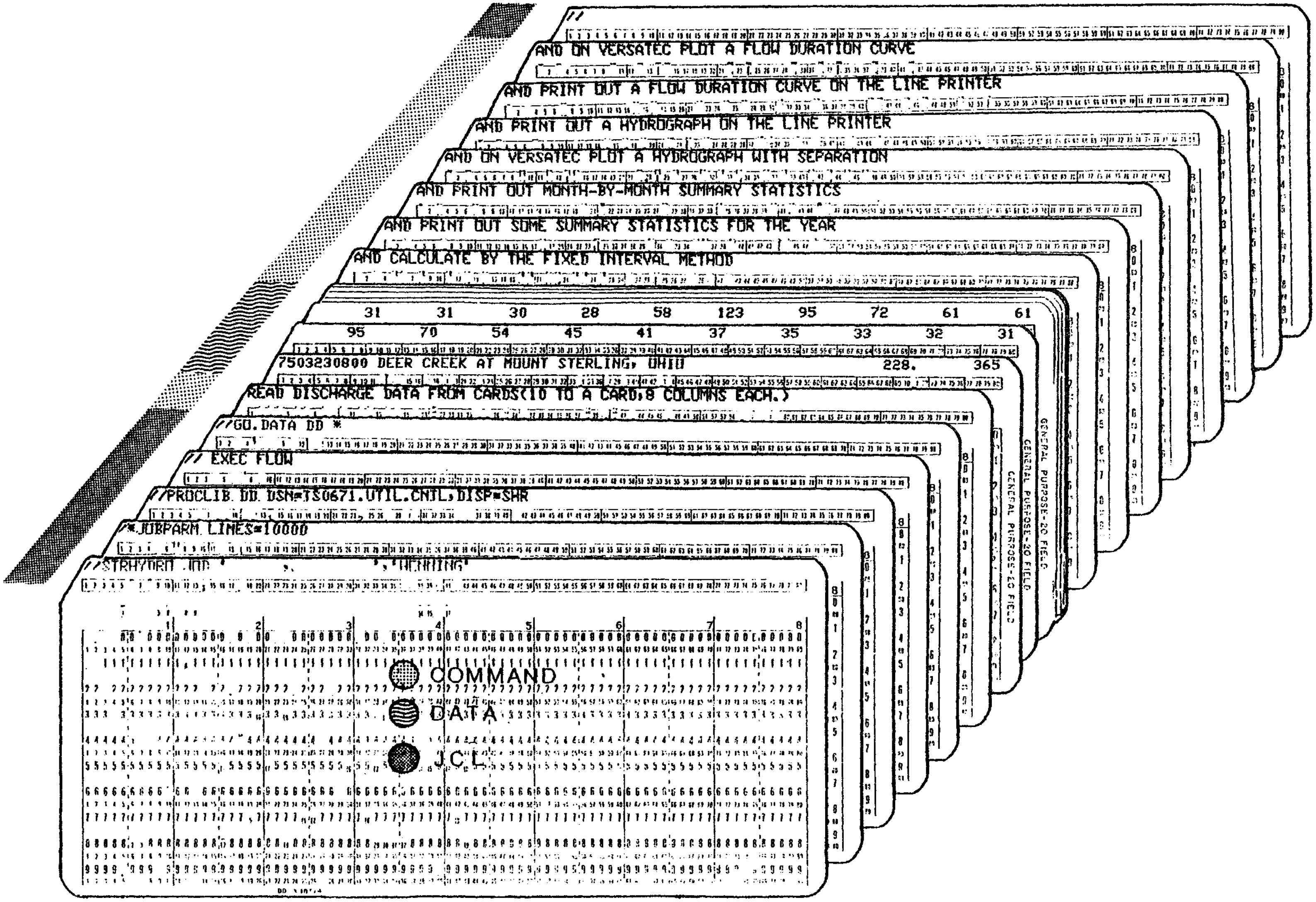



FIGURE 3-7. COMPUTER CARD ARRANGEMENT FOR VARIOUS OUTPUTS

format of "T", to read the card image at 20A4, return to the beginning of the record, and then read in necessary variables. If the program is to be used with a large number of stations, it would be advisable to install the REREAD capability.

Output from the Versatec or the various Calcomp plotting programs is not usable at other installations without major modification because the various CALL statements are based on the Ohio State University Instructional and Research Computer Center General Plotting Package (OSU IRCC GPP). Many installations have similar plotting packages. These subroutines can be easily adapted for use at these installations.

The line-printer hydrograph from the main separation program can be best utilized by manually connecting the symbols from total flow (+) and ground-water runoff (*) (fig. 3-6). Versatec hydrograph plots are much simpler to interpret because the size can be easily modified. Furthermore, these plots also include summary information. Warning messages that missing data exist are printed above the hydrograph. Figure 3-8 shows Versatec plots of the fixed interval, sliding interval, and local minima separation for Deer Creek.

The statistics for the fixed interval method are usually similar to the sliding interval, but those from local minima technique are considerably lower. Because the local minima method produces the most conservative values, this method is used to estimate regional recharge rates. This should not imply, however, that the authors believe that the local minima method is more correct than the other two. The most accurate method for each stream is probably dependent on the hydrogeologic conditions in each basin. Additional research is needed along these lines.

Line printer flow-duration curves are plotted as the log of the discharge per square mile of drainage basin versus an arithmetic-scaled percent of time

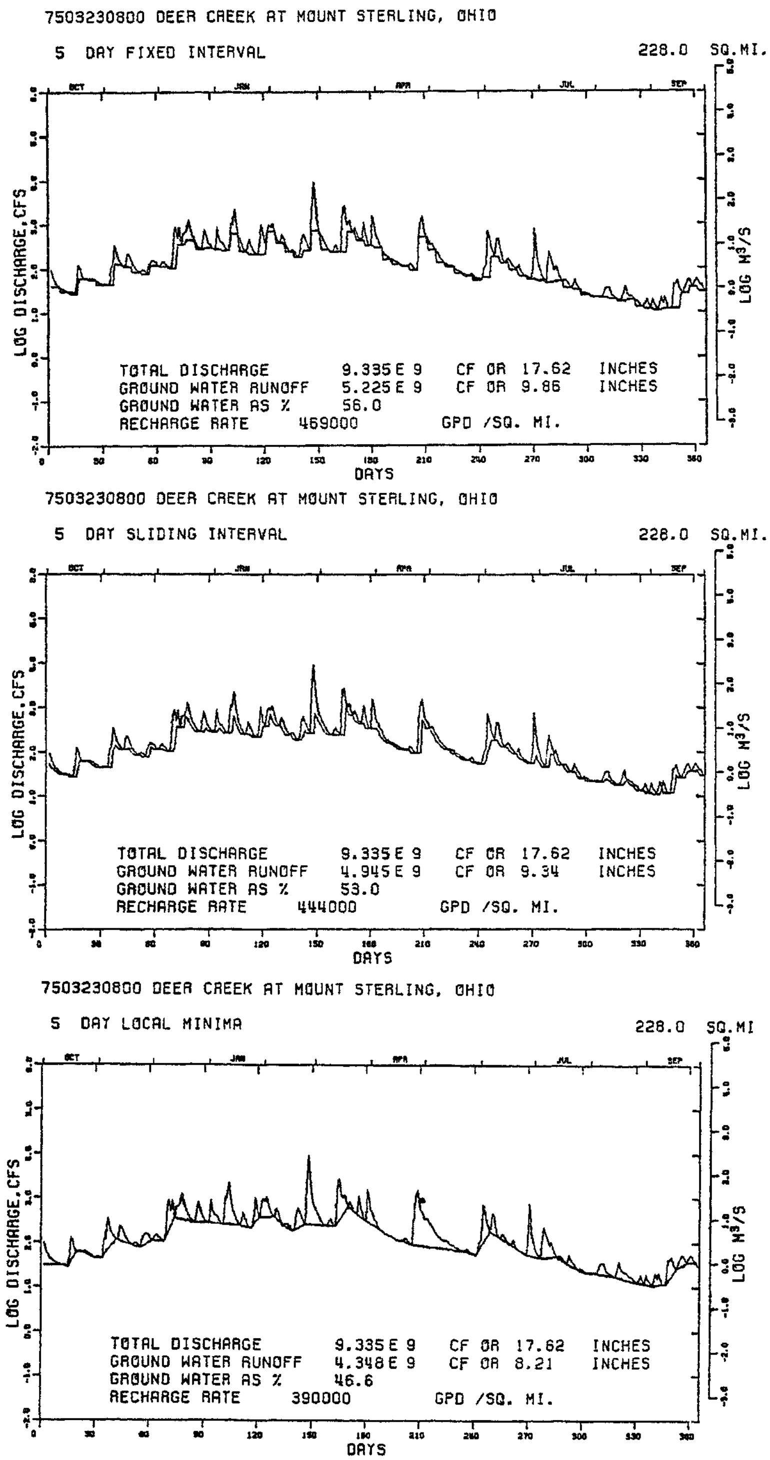



FIGURE 3-8. DEER CREEK HYDROGRAPHS SEPARATED BY THREE METHODS AND STATISTICAL DATA

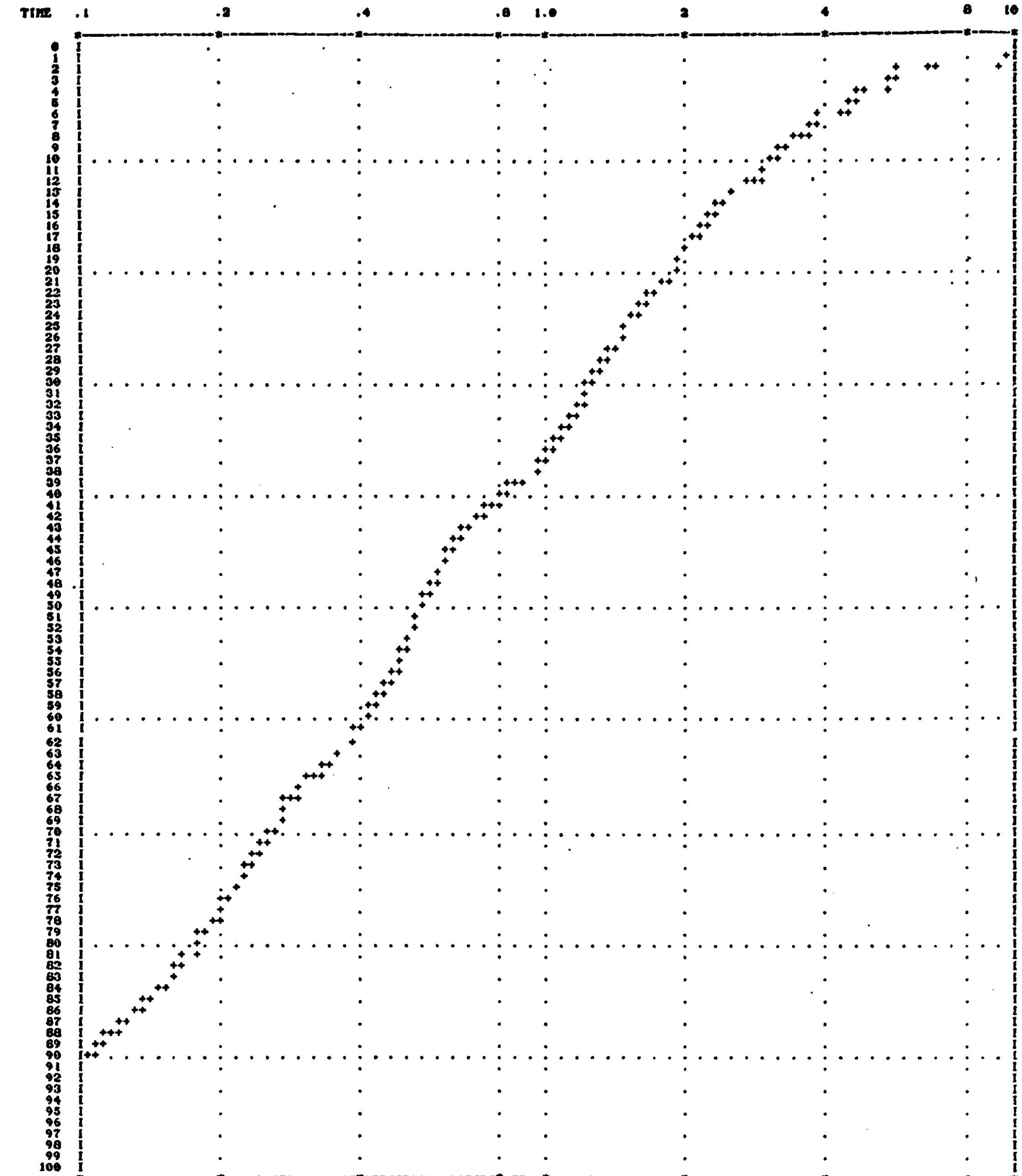
the discharge is equalled or exceeded. Curves of this form take on an S shape (fig. 3-9). A table of values listing each data element is also produced. The ratios of 10 to 90 and the 25 to 75 percent plots are printed below the table. If one or both of the ratios are invalid because the low flow is less than 0.01 cfs/sq. mi., a warning is printed above the ratios.

The Versatec flow-duration curve is plotted on a log probability graph, which permits detailed examination of the low-flow characteristics because of the expanded scale at the extremes (fig. 3-10). A normal distribution will plot as a straight line, but since streamflow is skewed because more values are below the mean than above it, the curve will deviate from the straight line depending on the stream's characteristics.

The shape of the curve is an index of natural storage in the basin of which ground water may be a major part. The more nearly horizontal the curve, the more ground-water storage there is in the basin. Caution should be used in interpreting flow-duration curves, because they are influenced by regulation and control as well as by municipal and industrial effluent. Information concerning control structures and, in some cases, effluent sources, can be found in the narrative of the station record but other reference sources may also need to be examined.

The portion of the flow-duration curve that provides the most information about ground-water storage is in the 60 to 99 percent range. Some workers have suggested that baseflow is equal to the 60 percent flow, but others believe it is more closely related to the 90 percent flow. Since the baseflow is derived from ground-water storage, except for anthropogenous sources, the 60 to 90 percent range is indicative of the nature of the groundwater/surface water interface. Ohio streams that flow through outwash filled valleys have gently sloping flow-duration curves that approach the horizontal beyond the

FLOW-DURATION CURVE FOR 7503230800 DEER CREEK AT MOUNT STERLING, OHIO 228.00 SQ.MI




FLOW-DURATION CURVE FOR 7503230800 DEER CREEK AT MOUNT STERLING, OHIO 228.00 SQ.MI

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100.00 | 0.048 | 99.73 | 0.053 | 99.45 | 0.053 | 99.18 | 0.053 | 98.90 | 0.053 | 98.63 | 0.057 | 98.36 | 0.057 | 98.08 | 0.057 |
| 97.81 | 0.061 | 97.53 | 0.066 | 97.26 | 0.066 | 96.99 | 0.066 | 96.71 | 0.066 | 96.44 | 0.066 | 96.16 | 0.070 | 95.89 | 0.075 |
| 95.62 | 0.079 | 95.34 | 0.079 | 95.07 | 0.083 | 94.79 | 0.083 | 94.52 | 0.083 | 94.25 | 0.083 | 93.97 | 0.088 | 93.70 | 0.088 |
| 93.42 | 0.092 | 93.13 | 0.092 | 92.88 | 0.092 | 92.60 | 0.092 | 92.33 | 0.096 | 92.05 | 0.096 | 91.78 | 0.096 | 91.51 | 0.096 |
| 91.23 | 0.096 | 90.96 | 0.096 | 90.68 | 0.096 | 90.41 | 0.096 | 90.14 | 0.101 | 89.86 | 0.105 | 89.59 | 0.110 | 89.32 | 0.110 |
| 89.04 | 0.114 | 88.77 | 0.114 | 88.49 | 0.114 | 88.22 | 0.118 | 87.95 | 0.123 | 87.67 | 0.123 | 87.40 | 0.123 | 87.12 | 0.123 |
| 86.85 | 0.127 | 86.58 | 0.127 | 86.30 | 0.132 | 86.03 | 0.132 | 85.75 | 0.136 | 85.48 | 0.136 | 85.21 | 0.136 | 84.93 | 0.140 |
| 84.66 | 0.140 | 84.38 | 0.145 | 84.11 | 0.145 | 83.84 | 0.149 | 83.56 | 0.154 | 83.29 | 0.158 | 83.01 | 0.158 | 82.74 | 0.158 |
| 82.47 | 0.158 | 82.19 | 0.162 | 81.92 | 0.162 | 81.64 | 0.162 | 81.37 | 0.162 | 81.10 | 0.167 | 80.82 | 0.167 | 80.55 | 0.175 |
| 80.27 | 0.175 | 80.00 | 0.175 | 79.73 | 0.180 | 79.45 | 0.180 | 79.18 | 0.184 | 78.90 | 0.184 | 78.63 | 0.184 | 78.36 | 0.193 |
| 78.08 | 0.193 | 77.81 | 0.197 | 77.53 | 0.197 | 77.26 | 0.197 | 76.99 | 0.202 | 76.71 | 0.202 | 76.44 | 0.202 | 76.16 | 0.202 |
| 75.89 | 0.206 | 75.62 | 0.211 | 75.34 | 0.213 | 75.07 | 0.215 | 74.79 | 0.219 | 74.52 | 0.219 | 74.25 | 0.224 | 73.97 | 0.224 |
| 73.70 | 0.220 | 73.42 | 0.228 | 73.15 | 0.237 | 72.88 | 0.237 | 72.60 | 0.237 | 72.33 | 0.237 | 72.05 | 0.237 | 71.78 | 0.241 |
| 71.51 | 0.241 | 71.23 | 0.246 | 70.96 | 0.250 | 70.68 | 0.250 | 70.41 | 0.250 | 70.14 | 0.254 | 69.86 | 0.259 | 69.59 | 0.263 |
| 69.32 | 0.268 | 69.04 | 0.268 | 68.77 | 0.268 | 68.49 | 0.268 | 68.22 | 0.272 | 67.95 | 0.272 | 67.67 | 0.272 | 67.40 | 0.272 |
| 67.12 | 0.276 | 66.85 | 0.281 | 66.58 | 0.289 | 66.30 | 0.289 | 66.03 | 0.298 | 65.75 | 0.298 | 65.48 | 0.303 | 65.21 | 0.307 |
| 64.93 | 0.316 | 64.66 | 0.329 | 64.38 | 0.329 | 64.11 | 0.329 | 63.84 | 0.333 | 63.56 | 0.342 | 63.29 | 0.351 | 63.01 | 0.355 |
| 62.74 | 0.360 | 62.47 | 0.377 | 62.19 | 0.382 | 61.92 | 0.390 | 61.64 | 0.390 | 61.37 | 0.390 | 61.10 | 0.390 | 60.82 | 0.390 |
| 60.55 | 0.399 | 60.27 | 0.408 | 60.00 | 0.417 | 59.73 | 0.417 | 59.45 | 0.417 | 59.18 | 0.417 | 58.90 | 0.421 | 58.63 | 0.425 |
| 58.36 | 0.430 | 58.08 | 0.430 | 57.81 | 0.430 | 57.53 | 0.439 | 57.26 | 0.452 | 56.99 | 0.461 | 56.71 | 0.461 | 56.44 | 0.469 |
| 56.16 | 0.469 | 55.89 | 0.474 | 55.62 | 0.482 | 55.34 | 0.482 | 55.07 | 0.482 | 54.79 | 0.482 | 54.52 | 0.482 | 54.25 | 0.491 |
| 53.97 | 0.491 | 53.70 | 0.500 | 53.43 | 0.509 | 53.15 | 0.504 | 52.88 | 0.509 | 52.60 | 0.509 | 52.33 | 0.513 | 52.05 | 0.518 |
| 51.78 | 0.526 | 51.51 | 0.526 | 51.23 | 0.531 | 50.96 | 0.531 | 50.68 | 0.531 | 50.41 | 0.539 | 50.14 | 0.539 | 49.86 | 0.544 |
| 49.59 | 0.544 | 49.32 | 0.548 | 49.04 | 0.548 | 48.77 | 0.557 | 48.49 | 0.561 | 48.22 | 0.570 | 47.95 | 0.570 | 47.67 | 0.579 |
| 47.40 | 0.583 | 47.12 | 0.588 | 46.85 | 0.588 | 46.58 | 0.592 | 46.30 | 0.596 | 46.03 | 0.596 | 45.75 | 0.605 | 45.48 | 0.610 |
| 45.21 | 0.618 | 44.93 | 0.618 | 44.66 | 0.632 | 44.38 | 0.632 | 44.11 | 0.654 | 43.84 | 0.658 | 43.56 | 0.658 | 43.29 | 0.662 |
| 43.01 | 0.671 | 42.74 | 0.671 | 42.47 | 0.697 | 42.19 | 0.706 | 41.92 | 0.719 | 41.64 | 0.732 | 41.37 | 0.746 | 41.10 | 0.759 |
| 40.82 | 0.763 | 40.55 | 0.781 | 40.27 | 0.794 | 40.00 | 0.811 | 39.73 | 0.816 | 39.45 | 0.829 | 39.18 | 0.860 | 38.90 | 0.882 |
| 38.63 | 0.899 | 38.36 | 0.952 | 38.08 | 0.952 | 37.81 | 0.963 | 37.53 | 0.978 | 37.26 | 0.978 | 36.99 | 0.991 | 36.71 | 1.013 |
| 36.44 | 1.018 | 36.16 | 1.035 | 35.89 | 1.053 | 35.62 | 1.053 | 35.34 | 1.053 | 35.07 | 1.066 | 34.79 | 1.066 | 34.52 | 1.075 |
| 34.25 | 1.083 | 33.97 | 1.092 | 33.70 | 1.114 | 33.42 | 1.127 | 33.15 | 1.145 | 32.88 | 1.154 | 32.60 | 1.154 | 32.33 | 1.167 |
| 32.05 | 1.184 | 31.78 | 1.197 | 31.51 | 1.202 | 31.23 | 1.211 | 30.96 | 1.215 | 30.68 | 1.215 | 30.41 | 1.232 | 30.14 | 1.246 |
| 29.85 | 1.250 | [illegible] | [illegible] | [illegible] | 1.231 | [illegible] | [illegible] | 28.77 | [illegible] | 28.49 | 1.311 | [illegible] | 1.311 | 27.95 | 1.311 |

(CONTINUES) BUT NOT INCLUDED

FIGURE 3-9. FLOW-DURATION CURVE AND FLOW PERCENTAGE LISTING (PARTIAL) PRODUCED BY LINE PRINTED

1 7503230800 DEER CREEK AT MOUNT STERLING, OHIO

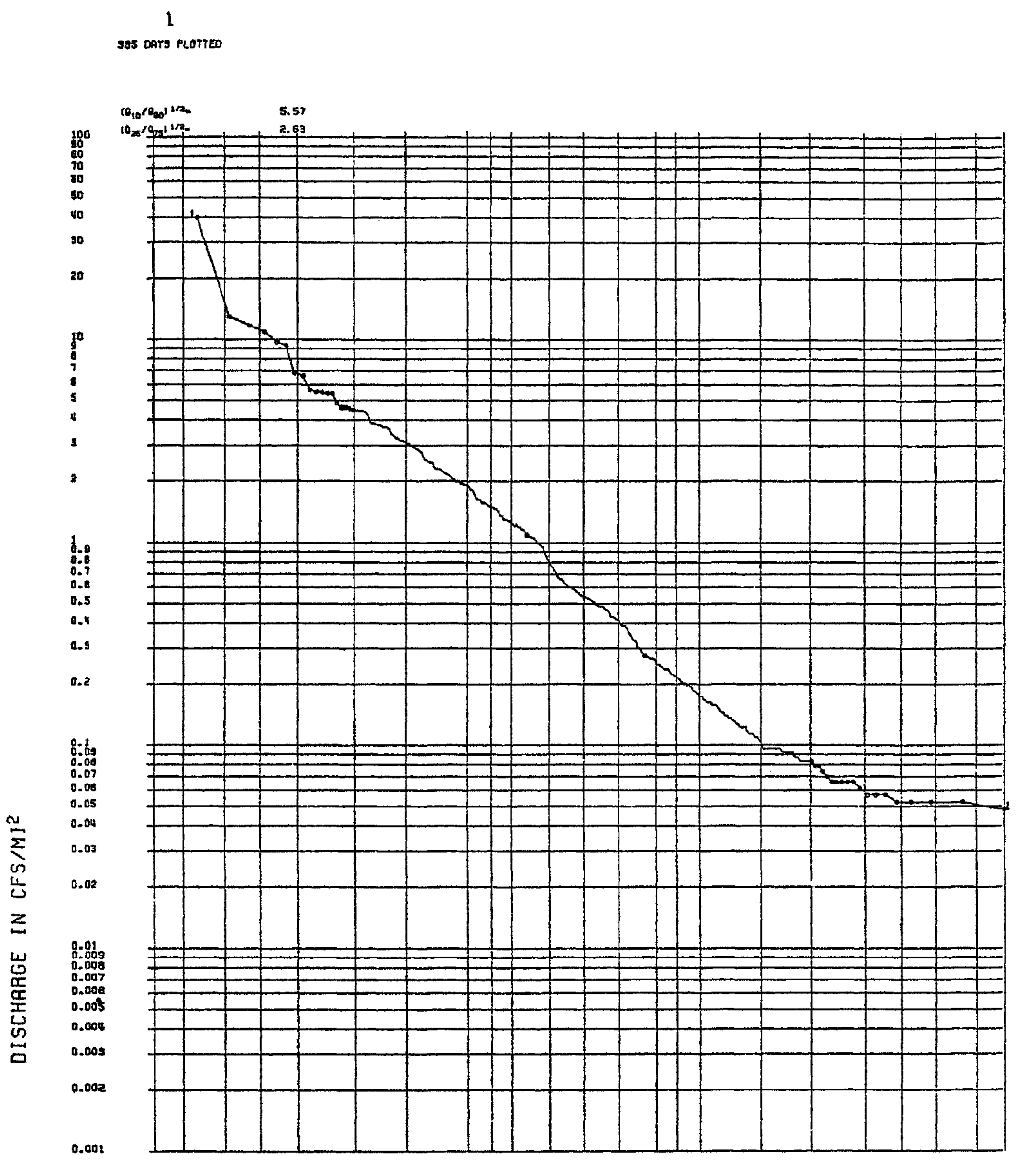



FIGURE 3-10. VERSATEC GENERATED FLOW-DURATION CURVE

60 percent flow. In streams of this type, baseflow probably occurs at about the 60 percent flow duration.

Streams whose channels are carved in shale or thick till are generally flashy. Flow-duration curves are steep and there is little or no flow part of the year. The steep curves indicate very little or no ground-water runoff at least during part of the year and, thus baseflow is indicated near the 90 percent flow.

The flow-duration plotting program indicates the beginning of no flow conditions by plotting a large asterisk at that point. At the top of the graph, the number of days of no flow is written under the number corresponding to that curve (fig. 3-11).

In order to compare flow-duration curves, both in time and space, another plotting program was developed that plots from one to six station year records for 1 to as many as 3 years (1095 days). In this way, the curves are all plotted on the same grid making it easy to compare and contrast them. In Figure 3-11, flow-duration curves were plotted by combining the records for 1963, 1967 and 1973, which were years of below normal, normal, and above normal precipitation, respectively. In this way, it is easier to obtain an understanding of the stream characteristics with only a few representative years record.

The curves for station 1, 2 and 3 are steep and indicate only a small basin storage capacity, while streams 4, 5 and 6 indicate relatively large ground-water storage. The latter basins contain aquifers with high sustained yields.

Figure 3-12 illustrates another valuable use of superimposed flow-duration curves. In this example, stations on the same stream are plotted on the same grid in order to detect where, if at all, the stream characteristics change. This example shows a stream whose characteristics are quite uniform throughout the basin.

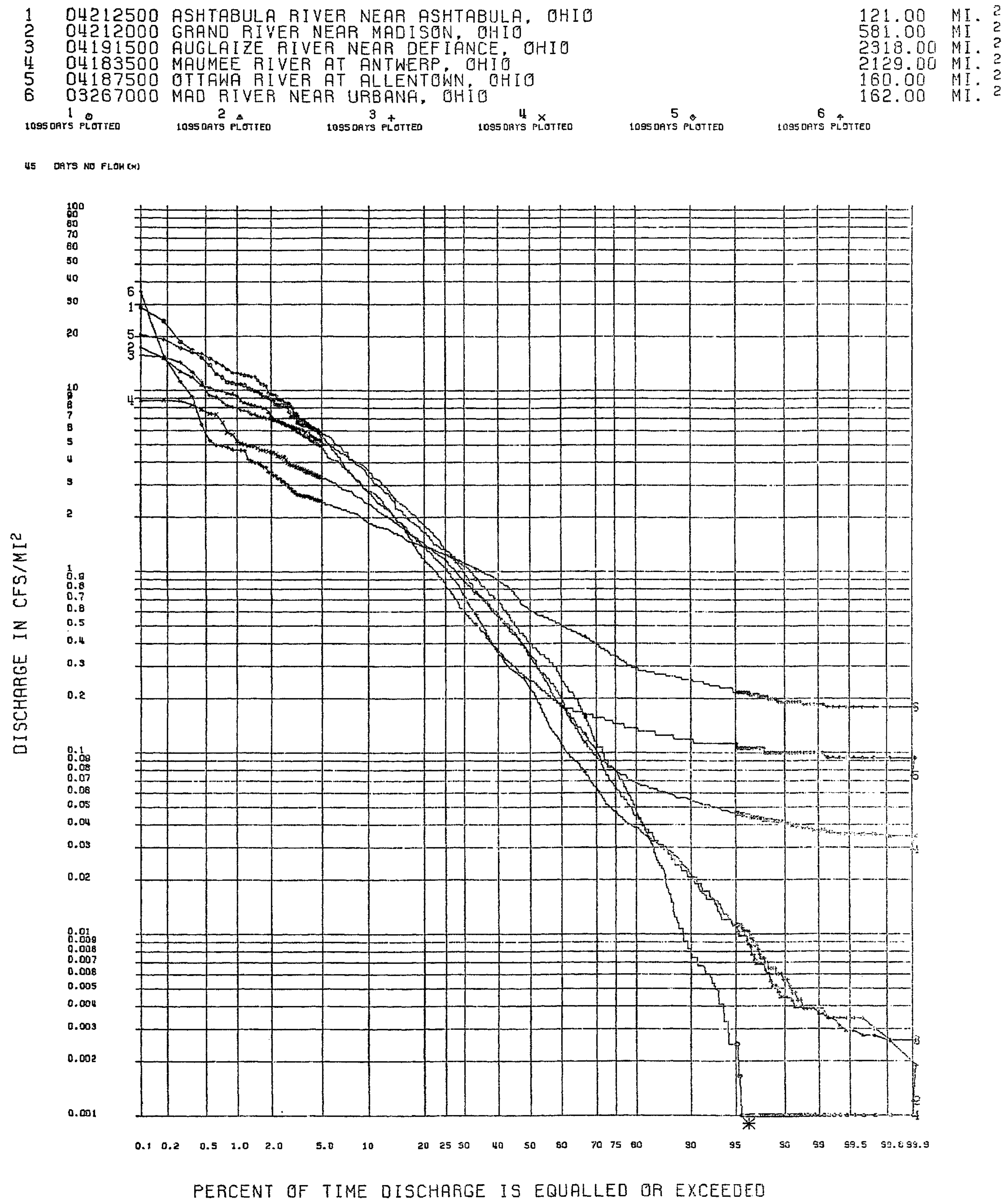



FIGURE 3-11. VERSATEC GENERATED FLOW-DURATION CURVES REPRESENTING SIX DIFFERENT STREAMS

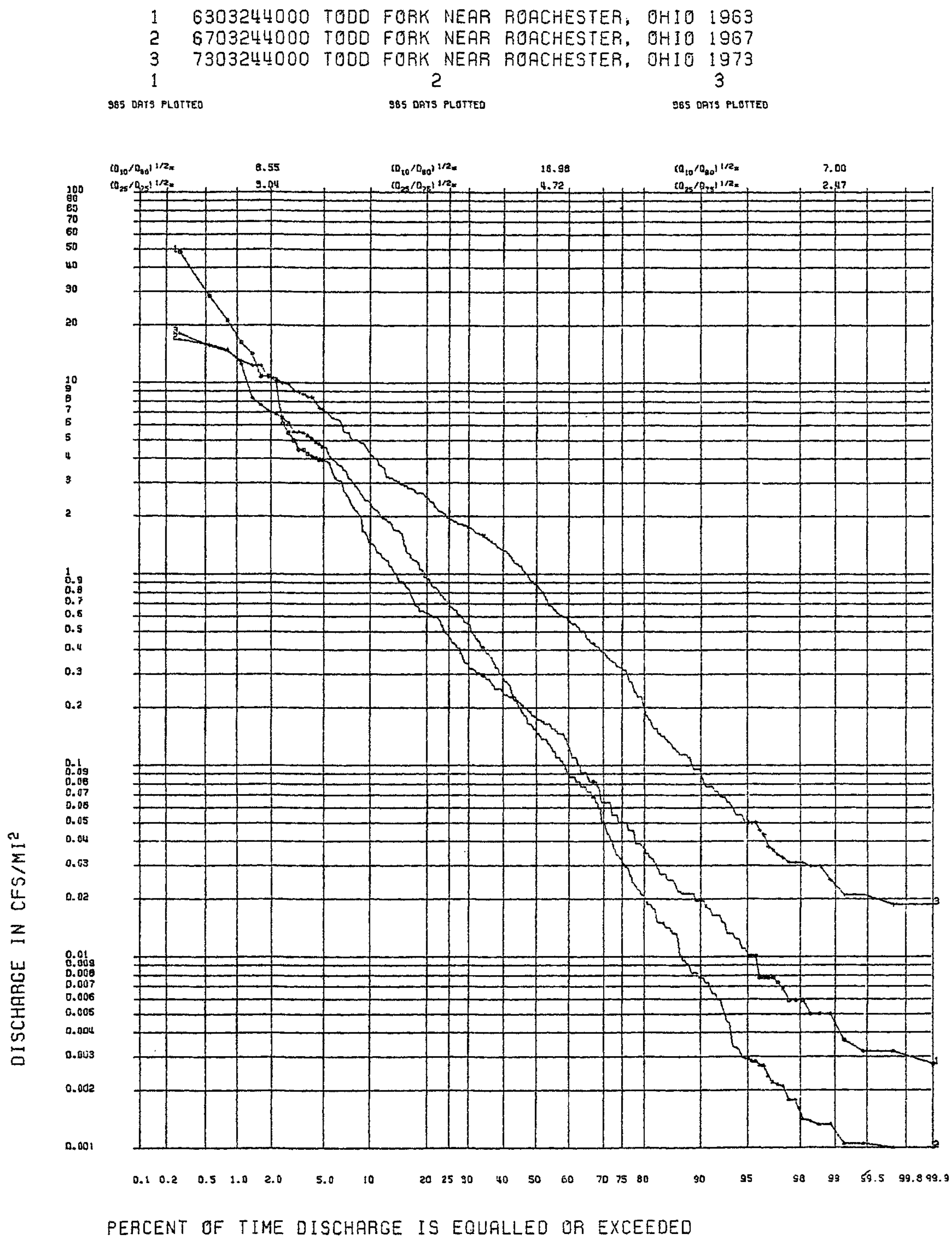



FIGURE 3-12. VERSATEC GENERATED FLOW-DURATION CURVES FOR THE SAME STREAM, BUT DIFFERENT YEARS

Partial record stations can be used to supplement the information derived from full record stations by comparing the discharge per square mile on a recorded day with that of nearby full record stations. The point plotted at the same percentage as the full record station value for that data can possibly indicate the offset of the curve that may apply to the partial record station. The relationship between the 90 percent flow and effective recharge rate can then be inferred from the synthetic flow duration curve. This relationship is being examined and will be discussed in more detail by Henning (in preparation).

Admittedly, this estimation is based on derived information from approximations, but if the researcher is careful and selects full record stations from similar geologic, physiographic, and hydrologic regimes, then the estimate of the characteristics of the partial record station should lie within a relatively narrow range of possibilities. Most important in this study is not the exact values derived at each individual point, but rather the trend of values. In this way, it is not as important that a particular station has a recharge rate of, say, 290,000 gpd/sq. mi., but rather than it be plausable in relation to other upstream or downstream situations, or those that occur in similar hydrogeologic settings. In deciding the value for the possible recharge rate of a partial record station, the value should always be treated as a range rather than a real number.

In order to determine the validity of the methods used in this study, several control or check methods are being considered. One method, currently under study, will employ a watershed simulation program with given inputs of water from various sources under differing conditions to produce a synthetic hydrograph. This hydrograph can then be digitized and used as input to the programs used in this study. Statistical analysis methods can then be employed to determine the suitability of these separation techniques to various geologic, physiographic, and hydrologic conditions.

Another approach, although perhaps less exact, involves comparing separations performed by widely-accepted manual methods with those used in this study. During this study such compositions were done in three different ways. First, three representative Ohio streams were chosen to cover a wide range of hydrographic conditions and basin size. Hydrographs were prepared and three manual methods of separation were applied. Ground-water runoff, expressed as a percentage of total flow, is shown in Table 3-I.

The discharge data were then card punched and separations were made by each of the three different computer techniques. Comparison of the results shows that the range of percentages from the manual separations is similar to the range of percentages from the computer separations for intervals close to 2N. It is interesting to note that the computer separations are more internally consistent between techniques and from year to year than are the manually derived statistics.

Because the straight line method is similar to the local minima method, a comparison of consistency between these two techniques shows similarity, with the greatest difference occurring in the dry year (1963). Close examination of the manual separation plot showed that inconsistent decisions were made concerning some long term events. Apparently the technicians made some unconscious adjustments or decisions as to where the ground-water component of runoff ought to be rather than exactly follow the methodology of the technique.

The validity of subjective decisions in hydrograph separation can be argued, despite the fact that subjective behavior differs from one individual to another. On the other hand, the computer techniques are purely objective and each set of identical data will consistently produce exactly the same results. Because the computer can not deviate from the precise method, internal consistency between stations is assured. The information may not be any better than an analysis by a skilled researcher, but it will certainly be more consistent.

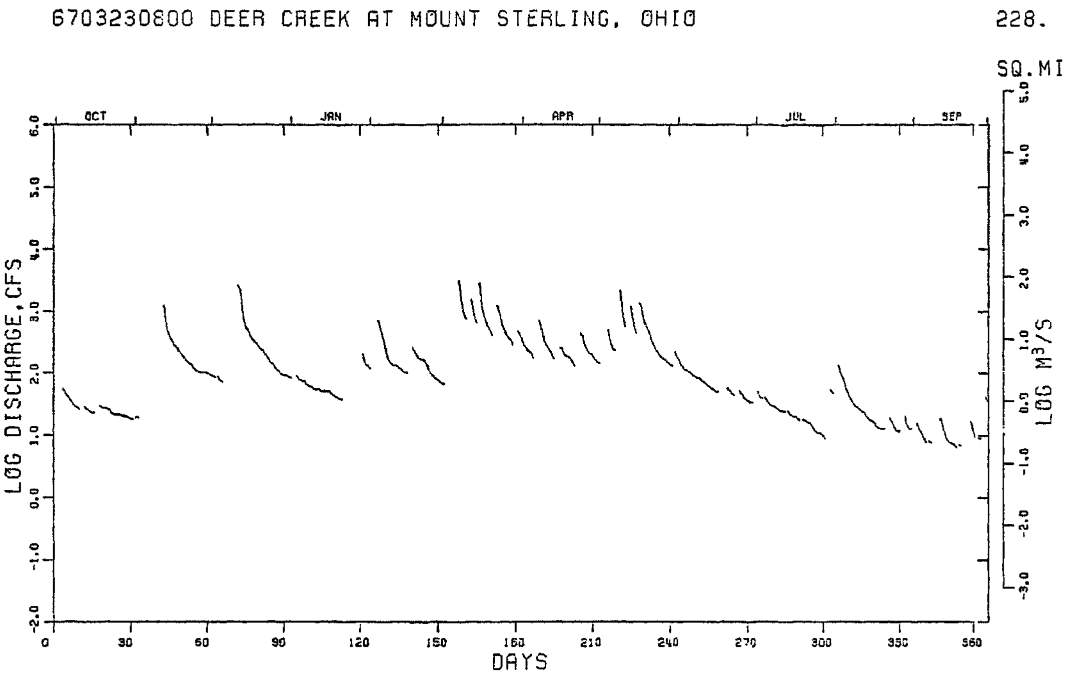
Another comparison was based on hydrograph separations of several Ohio streams by Tuller (1974). In his study, a computer program was used to plot stream hydrographs. (This program was the basis for the line-printer hydrograph subroutine of this study.) After the hydrographs were plotted, they were separated by manual application of the method where a straight line is drawn from the beginning of an event to a point N days from its crest. It is recognized that this method may provide a minimum value of ground-water runoff because it does not take into account the increase in ground-water runoff that may occur after storms.

Comparisons of 13 stations in the Scioto Basin are shown in Tables 3-II through 3-IV for the water years 1963, 1967, and 1973. Many of the values obtained by Tuller are very close to those determined during this study. The only significant difference is for those stations with very large or very small drainage areas. In the case of very large basins, the results for both techniques are questionable, at least in Ohio, because most large streams are regulated or influenced by municipal or industrial effects. Thus, under these circumstances, hydrograph separation is only a very approximate estimate. The data format does not lend itself well to the analysis of very small basins. Tuller assumed that a line connecting the individually plotted daily mean discharge values was a good approximation of the instantaneous hydrograph for a stream. This assumption is more correct for medium to large streams, but less so for small streams. Where N is less than 1.5, it is assumed that all effects of a precipitation event will end less than one and a half days after the crest. This means the daily mean discharge is only an estimate of a very steep recession curve. Since this study uses methods that compare the relationship of daily mean discharge then comparisons of values become less reliable as the size of the basin decreases. This concept also must apply to any manual method that assumes that the line connecting daily mean discharge is a good approximation of the instaneous hydrograph.

A third way used to test the performance of this study's techniques was to compare published results with those derived by our methods. Johnston (1976) analyzed the relation of ground water to surface water in four small basins in the Delaware Coastal Plain. Separation was done according to the method described by Riggs (1963), which is based on the preparation of a master base-flow recession curve that is overlain on the hydrograph to make the separation. Johnston's study included a 10-year period extending from 1959 to 1968. A summary of results from Johnston's study and the results we obtained after applying our techniques to the same 10 year data base are shown in Table 3-V.

In order to aid in understanding as much as possible about a stream, two additional graphic outputs are available in the Calcomp plotting program. These are useful in studying the recession characteristics of the stream. Figure 3-13 shows both the recession curve plot and the recession curve in the form of $q_o$ versus $q_1$. The plot of the recession curve versus time is nothing more than a hydrograph with rising limbs deleted. In this way, a better picture of the nature of the recession limbs can be visualized. If one wants to manually separate a stream hydrograph using the method of Riggs (1963), then this plot will assist in deriving the master recession curve. Also, a plot of this type allows the researcher to visually decide if the stream experiences seasonal differences in the recession curve.

The recession curve in the form of $q_o$ versus $q_1$, is useful in deriving the recession constant as described in Linsley, Kohler, and Paulhus (1975). In this plot, the value for the flow one day is plotted against the flow one



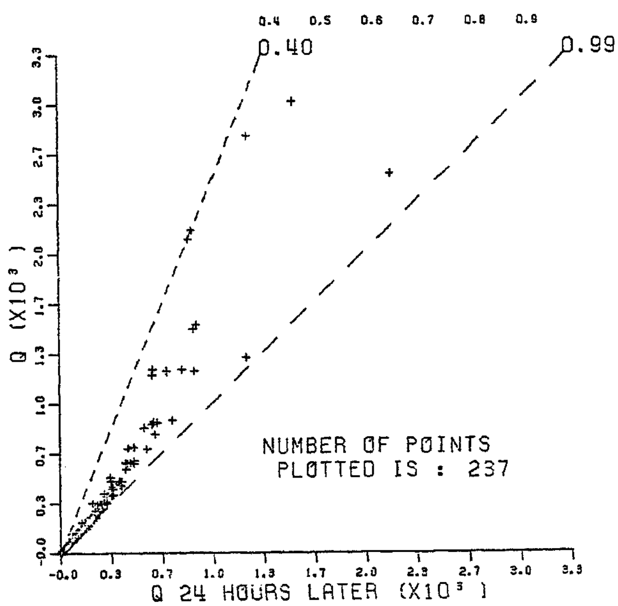




FIGURE 3-13. VERSATEC HYDROGRAPH SHOWING ONLY RECESSION LIMBS (UPPER) AND IN THE FORM $q_o$ VERSUS q

day later. Thus, this is a plot of the ratio of flows over a time period of one day. It is customary to draw the base-flow curve to envelop the slowest recession (highest ratio), that is, points to the right, because points deviating to the left may include direct runoff. The envelope to the left includes the highest direct-runoff recession. These ratios can be used in manually separating stream hydrographs using the recession curve method described in Linsley and others (1975). In terms of the value to researchers that choose to use the separation techniques of this study, the plots serve as additional sources of comparison of streams in similar or different hydrogeologic regimes. Differences in recession curves and recession constants, be they direct-runoff or base-flow, indicate differences in stream characteristics. It is these differences in basin characteristics that this study focuses upon.

Cost and time effectiveness is one of the most important factors in comparing manual and computer techniques for hydrograph separation. In order to put the methods in their proper perspective, some beginning assumptions need to be made. First, the cost of the computer does not enter into the evaluation, because it is assumed to be available at most research facilities. Secondly, the development of the computer programs, in terms of both time and money, are not considered, because the cost of developing manual methods by previous authors can not be estimated. This comparison will not be an evaluation of efficiency of research, but rather an evaluation of working interest.

The main points to be considered are:

1) time and cost of preparing data for evaluation.

2) time and cost of analyzing results.

3) recording and interpreting results.

Table 3-VI is a comparison of approximate costs incurred during this study.

The manual separation costs were averaged from time spent by a graduate student during separation of three hydrographs by means of the three different methods that were discussed earlier. The main points in the cost of the computer separation are similar, but, except for the digitizing of streamflow records, time is measured in microseconds and cost in cents. Costs may vary radically from one installation to another because of the wide differences in charging algorithms. At OSU, research computing time is billed at a very low rate, but since this program requires very little actual CPU time because of input/output bound, most of the cost is determined by the mode of output, rather than by actual computing time. If cost is determined only by actual CPU time, this program becomes extremely inexpensive, but if cost is based on amount of output or type of output, charges can be substantially more.

In summary, if the comparison is made between manual time and cost and computer time and cost, the question becomes moot. The machinery was developed to handle large amounts of data quickly and efficiently without random error, and with today's modern computers, it can do this task at far less cost than manual methods.

It is also important to consider the amount of data to be handled when deciding the relative merit of computer techniques. If only one station were to be analyzed, then it would not be worth the time and effort to install the program. But, if large numbers of stations are to be analyzed, then the time and effort would be well spent. Also, once the data are machine readable, many different analyses can be done and many different output modes can be obtained at a minimal expense. Also, Versatec output is of high quality and can be used directly in reports without redrafting.

As mentioned earlier, if the separation was to be done by hand, then it would be important to decide which was the best method, but since the program can do many different methods with very insignificant differences in time and cost, many different techniques can be tried. It is then up to the individual researcher to make use of the results as he himself finds best.

TABLE 3-1 COMPARISON OF MANUAL AND COMPUTER SEPARATIONS
(AS % OF TOTAL FLOW)

| | | MANUAL | | | COMPUTER | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | N | STRAIGHT LINE | RECESSION EXTENSION | REGRESSION CONSTANT | FIXED 3 | FIXED 5 | FIXED 7 | SLIDING 3 | SLIDING 5 | SLIDING 7 | LOCAL MINIMA 3 | LOCAL MINIMA 5 | LOCAL MINIMA 7 |
| 03237280 | UPPER TWIN CREEK AT McGAW, OH. | | | | | | | | | | | | |
| 1973 | 2.3 | 51.84 | 62.03 | 65.25 | 65.06 | 55.40 | 51.54 | 66.91 | 56.90 | 51.31 | 57.10 | 54.48 | 50.89 |
| 1967 | 2.3 | 35.67 | 45.86 | 47.86 | 57.38 | 41.10 | 35.98 | 54.50 | 43.62 | 37.28 | 44.37 | 42.38 | 30.45 |
| 03230500 | BIG DARBY CREEK AT DARBYVILLE, OH. | | | | | | | | | | | | |
| 1973 | 3.5 | 51.27 | 46.68 | 64.91 | 69.40 | 59.65 | 52.79 | 71.20 | 59.11 | 53.31 | 63.96 | 55.10 | 53.09 |
| 1967 | 3.5 | 35.46 | 42.33 | 55.09 | 72.09 | 60.36 | 50.54 | 71.79 | 59.49 | 52.02 | 50.70 | 49.62 | 41.70 |
| 1963 | 3.5 | 28.37 | 34.54 | 39.08 | 57.34 | 46.63 | 43.86 | 62.14 | 46.71 | 38.42 | 42.57 | 42.10 | 31.25 |
| 04198000 | SANDUSKY RIVER NEAR FREMONT, OH. | | | | | | | | | | | | |
| 1973 | 4.0 | 38.95 | 36.76 | 46.89 | 70.23 | 48.63 | 44.06 | 68.65 | 51.20 | 43.63 | 48.31 | 45.10 | 38.66 |
| 1967 | 4.0 | 30.05 | 34.63 | 36.18 | 70.19 | 47.84 | 34.63 | 69.49 | 38.06 | 42.21 | 30.80 | 30.00 | 30.00 |
| 1963 | 4.0 | 22.75 | 32.26 | 36.26 | 77.45 | 49.57 | 37.33 | 72.42 | 54.75 | 45.01 | 47.53 | 40.65 | 30.40 |

TABLE 3-2 COMPARISON OF STATISTICS DETERMINED BY MANUAL AND COMPUTER METHODS

WATER YEAR 1963

| STATION | N | PERCENT GROUND WATER RUNOFF MANUAL | (COMPUTER) FIXINT | (COMPUTER) SLINTR | (COMPUTER) LOCMIN | RECHARGE RATE 1000 GPD/SQ. MI. MANUAL | (COMPUTER) MINIMUM | (COMPUTER) MAXIMUM |
|---|---|---|---|---|---|---|---|---|
| 03202000 | 3.5 | 33 | 50 | 47 | 37 | 228 | 263 | 332 |
| 03219500 | 3.5 | 32 | 43 | 46 | 40 | 124 | 153 | 176 |
| 03220000 | 2.8 | 31 | 36 | 34 | 26 | 104 | 88 | 123 |
| 03223000 | 2.7 | 31 | 34 | 35 | 32 | 149 | 161 | 173 |
| 03224500 | 2.5 | 33 | 38 | 37 | 28 | 170 | 146 | 190 |
| 03229000 | 2.8 | 35 | 32 | 33 | 27 | 160 | 124 | 153 |
| 03230500 | 3.5 | 35 | 44 | 38 | 31 | 142 | 127 | 179 |
| 03231000 | 3.2 | 32 | 37 | 35 | 27 | 157 | 133 | 182 |
| 03231500 | 5.2 | 32 | 52 | 53 | 44 | 140 | 186 | 231 |
| 03232500 | 2.7 | 48 | 54 | 47 | 38 | 298 | 238 | 335 |
| 03234000 | 3.8 | 41 | 48 | 45 | 35 | 266 | 227 | 312 |
| 03234500 | 5.5 | 48 | 51 | 51 | 46 | 234 | 221 | 245 |
| 03235500 | 1.0 | 27 | 36 | 39 | 36 | 145 | 267 | 280 |

TABLE 3-3 COMPARISON OF STATISTICS DETERMINED BY MANUAL AND COMPUTER METHODS

WATER YEAR 1967

| STATION | N | PERCENT GROUND WATER RUNOFF | | | | RECHARGE RATE 1000 GPD/SQ. MI. | | |
|---|---|---|---|---|---|---|---|---|
| | | | (COMPUTER) | | | | (COMPUTER) | |
| | | MANUAL | FIXINT | SLINTR | LOCMIN | MANUAL | MINIMUM | MAXIMUM |
| 03202000 | 3.5 | 31 | 54 | 55 | 50 | 227 | 367 | 407 |
| 03219500 | 3.5 | 33 | 41 | 44 | 35 | 201 | 217 | 273 |
| 03220000 | 2.8 | 29 | 34 | 36 | 35 | 185 | 217 | 227 |
| 03223000 | 2.7 | 31 | 43 | 45 | 34 | 223 | 245 | 322 |
| 03224500 | 2.5 | 34 | 41 | 43 | 45 | 230 | 280 | 306 |
| 03229000 | 2.8 | 38 | 37 | 40 | 42 | 267 | 258 | 291 |
| 03230500 | 3.5 | 45 | 51 | 52 | 42 | 268 | 246 | 307 |
| 03231000 | 3.2 | 42 | 50 | 49 | 46 | 270 | 291 | 321 |
| 03231500 | 5.2 | 50 | 48 | 47 | 47 | 320 | 299 | 305 |
| 03232500 | 2.7 | 42 | 66 | 66 | 59 | 306 | 310 | 346 |
| 03234000 | 3.8 | 50 | 53 | 54 | 52 | 294 | 307 | 316 |
| 03234500 | 5.5 | 51 | 50 | 49 | 49 | 335 | 321 | 323 |
| 03235500 | 1.0 | 35 | 58 | 56 | 46 | 240 | 323 | 411 |

TABLE 3-4 COMPARISON OF STATISTICS DETERMINED BY MANUAL AND COMPUTER METHODS

WATER YEAR 1973

| STATION | N | PERCENT GROUND WATER RUNOFF | (COMPUTER) | | | RECHARGE RATE 1000 GPD/SQ. MI. | (COMPUTER) | |
|---|---|---|---|---|---|---|---|---|
| | | MANUAL | FIXINT | SLINTR | LOCMIN | MANUAL | MINIMUM | MAXIMUM |
| 03202000 | 3.5 | 46 | 62 | 62 | 55 | 385 | 464 | 521 |
| 03219500 | 3.5 | 43 | 49 | 50 | 44 | 396 | 407 | 460 |
| 03220000 | 2.8 | 37 | 44 | 42 | 37 | 324 | 320 | 360 |
| 03223000 | 2.7 | 45 | 45 | 45 | 42 | 430 | 402 | 430 |
| 03224500 | 2.5 | 48 | 47 | 46 | 42 | 518 | 453 | 503 |
| 03229000 | 2.8 | 40 | 46 | 46 | 42 | 440 | 463 | 505 |
| 03230500 | 3.5 | 59 | 53 | 53 | 53 | 577 | 525 | 526 |
| 03231000 | 3.2 | 49 | 51 | 51 | 45 | 532 | 492 | 564 |
| 03231500 | 5.2 | 54 | 56 | 57 | 54 | 568 | 568 | 592 |
| 03232500 | 2.7 | 61 | 63 | 64 | 59 | 681 | 657 | 711 |
| 03234000 | 3.8 | 59 | 60 | 58 | 56 | 578 | 548 | 580 |
| 03234500 | 5.5 | 62 | 58 | 59 | 57 | 637 | 590 | 606 |
| 03235500 | 1.0 | 37 | 44 | 46 | 43 | 356 | 409 | 436 |

TABLE 3-5 COMPARISON BETWEEN PUBLISHED VALUES FOR FOUR SMALL BASINS IN DELAWARE WITH VALUES FOR THOSE BASINS COMPUTED BY LOCAL MINIMA

| | BEAVERDAM BRANCH | SOWBRIDGE BRANCH | STOCKLEY BRANCH | NANTICOKE RIVER |
|---|---|---|---|---|
| Average Total (Johnson) Runoff (inches) | 17 | 18 | 16 | 16 |
| Total Runoff Computed (inches) | 16.6 | 17.6 | 16.1 | 16.2 |
| Ground-Water (Johnson) Runoff (inches) | 13 | 14 | 13 | 12 |
| Ground-Water Runoff Computed (inches) | 13.4 | 15.4 | 13.6 | 12.4 |

TABLE 3-6 RELATIVE COST EFFECTIVENESS
(PER STATION/YEAR)

| MANUAL SEPARATION | | |
|---|---|---|
| PLOTTING DISCHARGE | 2.0 HR | $ 10,00 * |
| GROUNDWATER SEPARATION | 1.0 " | 5.00 |
| DATA TRANSFER AND CALCULATIONS | 1.5 " | 7.50 |
| TOTAL COST PER SEPARATION: | | $ 22.50 |

| COMPUTER SEPARATION | | |
|---|---|---|
| KEYPUNCHING DISCHARGE | 0.2 HR | $ 1.00* |
| COMPUTER SEPARATION (SUMMARY) | 0.00:00.05 | $ 0.025# |
| WITH HYDROGRAPH (PRINTER) | 0.00:02.00 | 0.90 |
| WITH HYDROGRAPH (CALCOMP) | 0.00:00.42 | 0.45 |
| WITH HYDROGRAPH (VERSATEC) | (EST.) | 0.20 |
| | | $ 1.02 - 1.90 |

( * - BASED ON $ 5.00 PER HOUR)

( # - BASED ON OSU CHARGING ALGORITHM)

## CHAPTER 4

## HYDROGEOLOGIC SETTING IN OHIO

### Geology and Physiography

The bedrock in Ohio is dominated by Paleozoic strata that dip slightly away from the axis of the Findlay Arch, which trends northeastward from Cincinnati to Lake Erie between Toledo and Marblehead Peninsula. Beds gently dip to the northwest west of the axis of the arch and to the southeast on the east side. Permian and Pennsylvanian age strata, which crop out or underlie much of the eastern half of Ohio, consist largely of alternating layers of sandstone and shale with minor amounts of coal, fireclay and limestone. Mississippian age sandstone and shale crop out or subcrop beneath the drift along a band extending northward from Portsmouth to within a few miles of Lake Erie as well as in extreme northwestern Ohio. To the north, these sandstone units commonly form the caprock along the edge of the Appalachian Plateau. Devonian age shale crops out along stream channels or underlies the drift through central Ohio, along the eastern shoreline of Lake Erie, and in a band in the northwest corner of the state. The southwest corner of the state consists of relatively thin, alternating layers of shale and limestone of Ordovician age, while much of the rest of the western half is underlain by Silurian age limestone and dolomite. The generalized areal extent of major near surface bedrock units and outwash valleys are shown in Figure 4-1.

The southeastern third of the state was not glaciated and here the topography is characterized by rolling hills and scattered strip mines. Elsewhere, glacial deposits mantle the surface and form a nearly flat region except where streams are deeply incised into the till or underlying bedrock. Several of the major river valleys, including the Mad, Great Miami, Scioto, Hocking, Tuscarawas, and Muskingum, contain extensive deposits of sand and gravel, which,

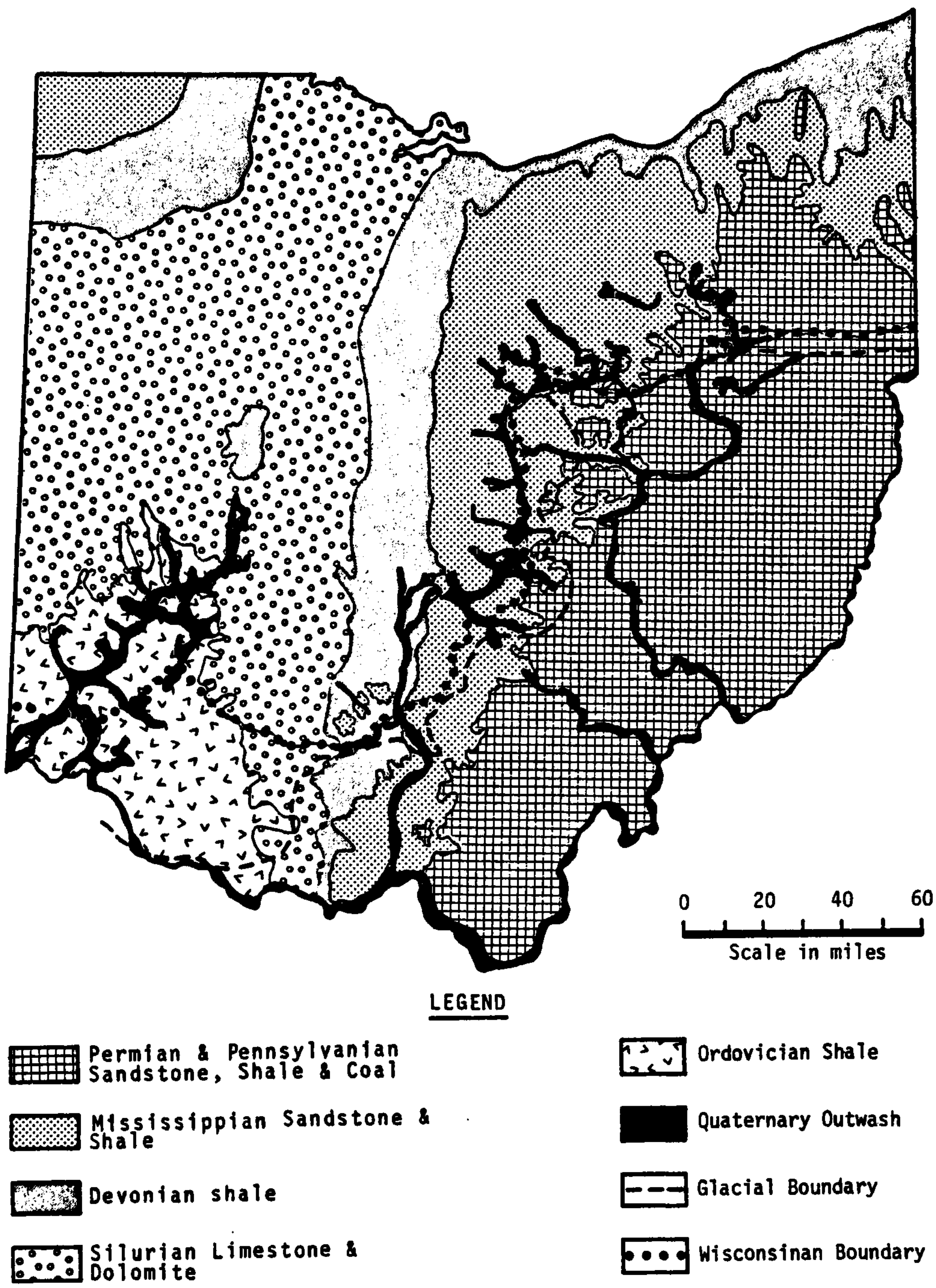


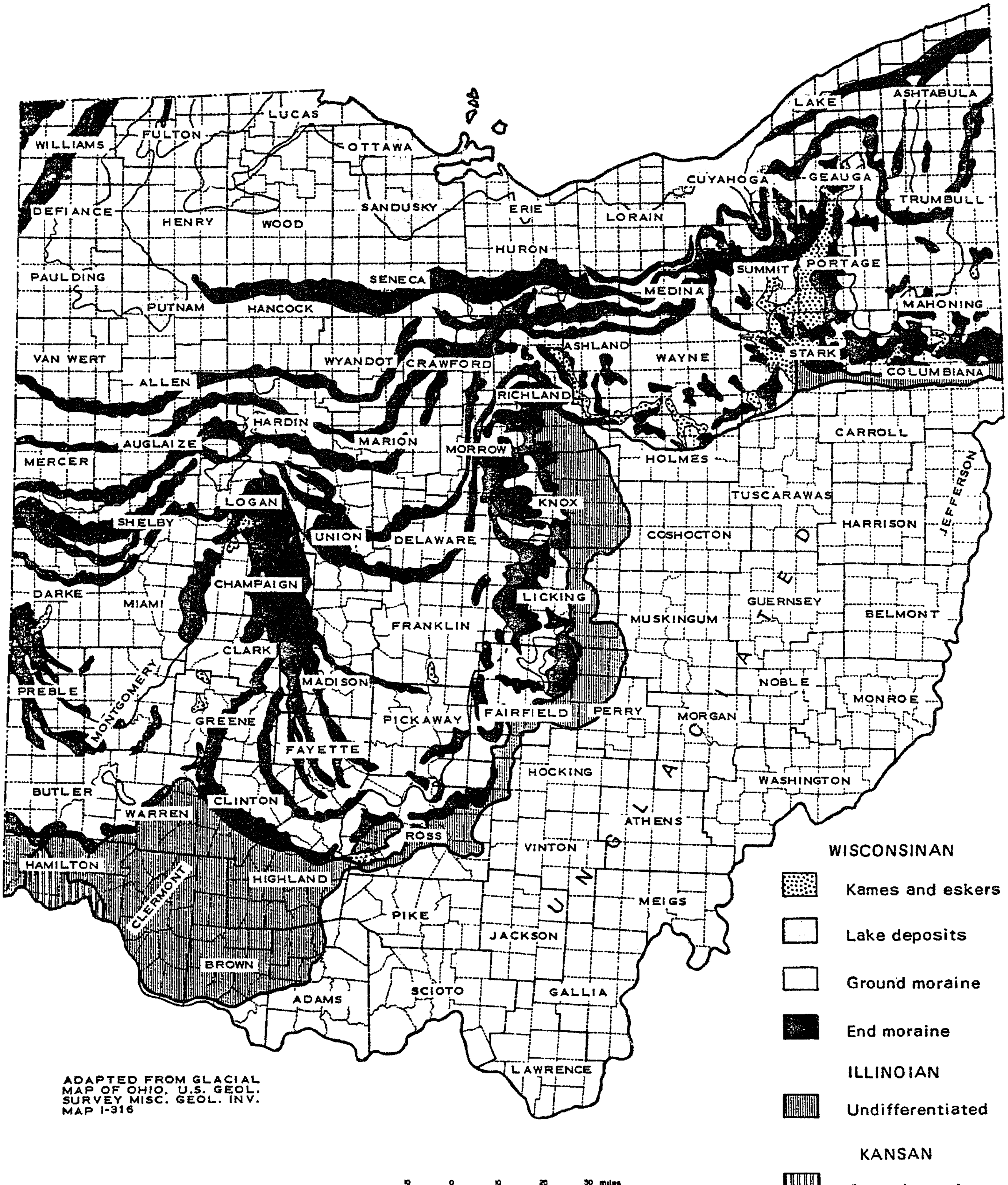

FIGURE 4-1. GENERALIZED GEOLOGIC MAP OF OHIO

along with similar deposits adjacent to the Ohio River, provide large quantities of water to wells.

In general, where glacial deposits overlie limestone, thicknesses range widely, from very thin to more than a hundred feet. Where glacial deposits overlie shale and sandstone, till thicknesses range from as much as 200 feet in the north to only scattered patches in the south. Stratified drift and moraines that contain substantial amounts of buried outwash add greatly to streamflow but they are scattered and variable in thickness. The distribution of the glacial units, exclusive of many of the surficial outwash deposits, are shown in Figure 4-2.

Ohio lies within two major physiographic provinces; the Central Lowland and the Appalachian Plateaus. The Central Lowland occupies the low relief and low elevation northwestern half of the state. The Appalachian Plateaus lie to the southeast and where glaciated the terrain is not unlike the Central Lowlands but elsewhere it is a mature hilly country, deeply dissected by a well-developed network of rivers that are tributary to the Ohio River. The landforms of Ohio are illustrated in Figure 4-3. The two major physiographic provinces in Ohio can be divided further into five different landform regions, which include (1) the unglaciated Appalachian Plateaus, (2) the glaciated Appalachian Plateaus, (3) the Central Lowlands Till Plains, (4) the Central Lowlands Lake Plains, and (5) the unglaciated Lexington Plain (fig. 4-4).

The unglaciated Appalachian Plateau is of moderate elevation, and dissected to such an extent that it is characterized by narrow ridges and hills and steep-sided valleys. Narrow floodplains border the major water courses. Oil and gas wells are common as are coal strip and underground mines. Locally infiltration has been greatly increased by the permeable spoil banks that act as large ground-water reservoirs. Underground mining also has had some




Glacial deposits of Ohio (Ohio Division of Geological Survey).

FIGURE 4-2. GLACIAL DEPOSITS IN OHIO


FIGURE 4-3. LANDFORMS OF OHIO

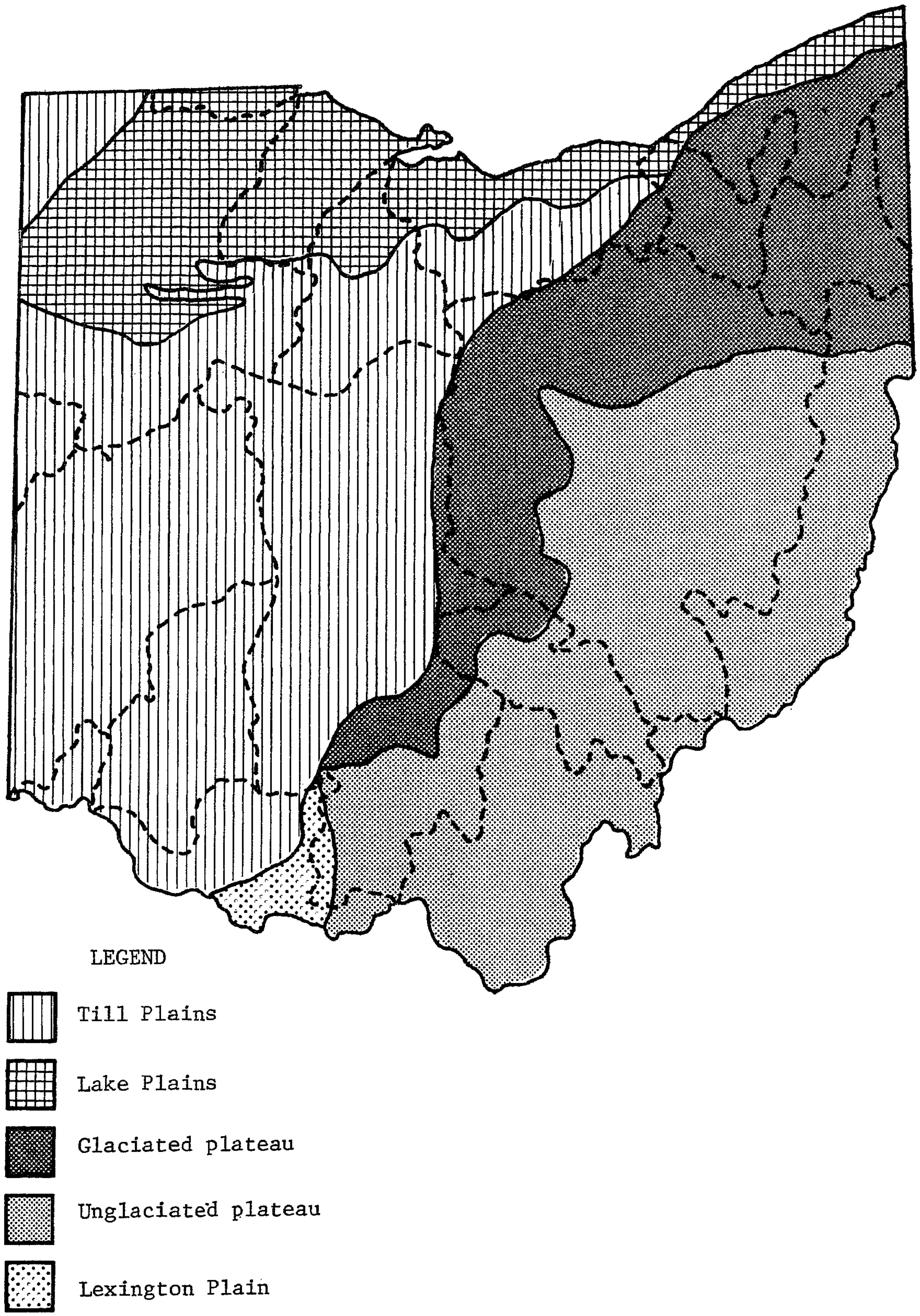



FIGURE 4-4. PHYSIOGRAPHIC SECTIONS OF OHIO

effect on stream flow in areas where acid-mine drainage discharges from shafts. Abandoned oil and gas wells do not measurably affect stream flow, but may have an adverse effect on the quality of both ground and surface water.

The remainder of the Appalachian Plateaus in Ohio have been modified by glaciation, which subdued the topography by erosion and deposition. To some extent the original drainage pattern has been displaced and buried valleys, small lakes, and poorly drained areas are not uncommon. Some coal mining and oil and gas development occur in the region, but they do not have the same affect on baseflow as in the unglaciated section.

The Till Plains, which cover about a third of Ohio, are characterized by low relief ground moraine and arcuate morainal ridges. The surface is nearly flat or, at most, gently rolling in the vicinity of end moraines. The bedrock surface below the till locally has considerable relief, particularly in the vicinity of buried valleys. Most of the ground-water runoff in this region originates from sand and gravel deposits within end moraines and very little is derived from the thick tills. Outwash-filled valleys and buried valleys are much more significant in the southern part of this region and are the major sources of the high dry-weather flow in the Miami basin, and specifically in the Mad River basin.

The Lake Plains cover a wide path generally parallel to the Maumee River and Lake Erie. Here fine-grained lake-bed deposits predominate and these are locally interrupted by narrow sandy beach ridges. Because of the very low relief in this region, the beach ridges, which are only a few feet high, stand out as prominent topographic features. They are important sources for domestic water supply, but do not contribute significantly to baseflow.

The Lexington Plain occurs only in Adams and parts of Highland and Brown Counties where it is drained by Ohio Brush and Eagle Creeks. Bedrock consists of nearly flat-lying limestone that contains numerous sinkholes and irregular depressions, particularly on the uplands. The area is deeply dissected, and baseflow, although quite low, probably originates from the Brassfield Limestone of Silurian age and, locally, from alluvium.

Climate

Ohio's climate is classified as humid-continental warm-summer type according to Trewartha's adaptation of the Koeppen system (1954). The general characteristics as noted by Noble (1975) are, (1) pronounced seasonal shifts of temperature, (2) alternation of irregularly spaced high-and low-pressure air masses, (3) winter season dominated by polar continental air masses with brief interjections of tropical maritime air, which brings warm, wet weather, (4) summer dominated by tropical maritime and continental tropical air masses, which produce high temperatures and moderate to high humidity, (5) somewhat higher rainfall in summer than winter, (6) wide range of annual temperature, (7) small diurnal temperature changes, (8) prevailing winds from the west, northwest, or southwest, (9) moderate cloud cover in summer and greater in winter, and (10) occasional tornadoes, especially in early spring.

Even though temperatures in Ohio are generally moderate (fig. 4-5), extremes are far more significant than the means. Extremely low temperatures are not uncommon at most stations and unusually cold temperatures even occur during the summer. The highest temperatures are generally found in the northwest and along the Ohio River Valley. Other than the area moderated by the effect at Lake Erie, extreme changes in temperature are not uncommon.

Precipitation totals are moderate (fig. 4-6). The average annual precipitation for the state is 38 inches. During the water years with below normal, normal, and above normal precipitation (1963, 1967, and 1973, respectively) annual precipitation ranged from less than 20 to 40, 30 to 40, and


FIGURE 4-5. GENERALIZED MEAN ANNUAL TEMPERATURE

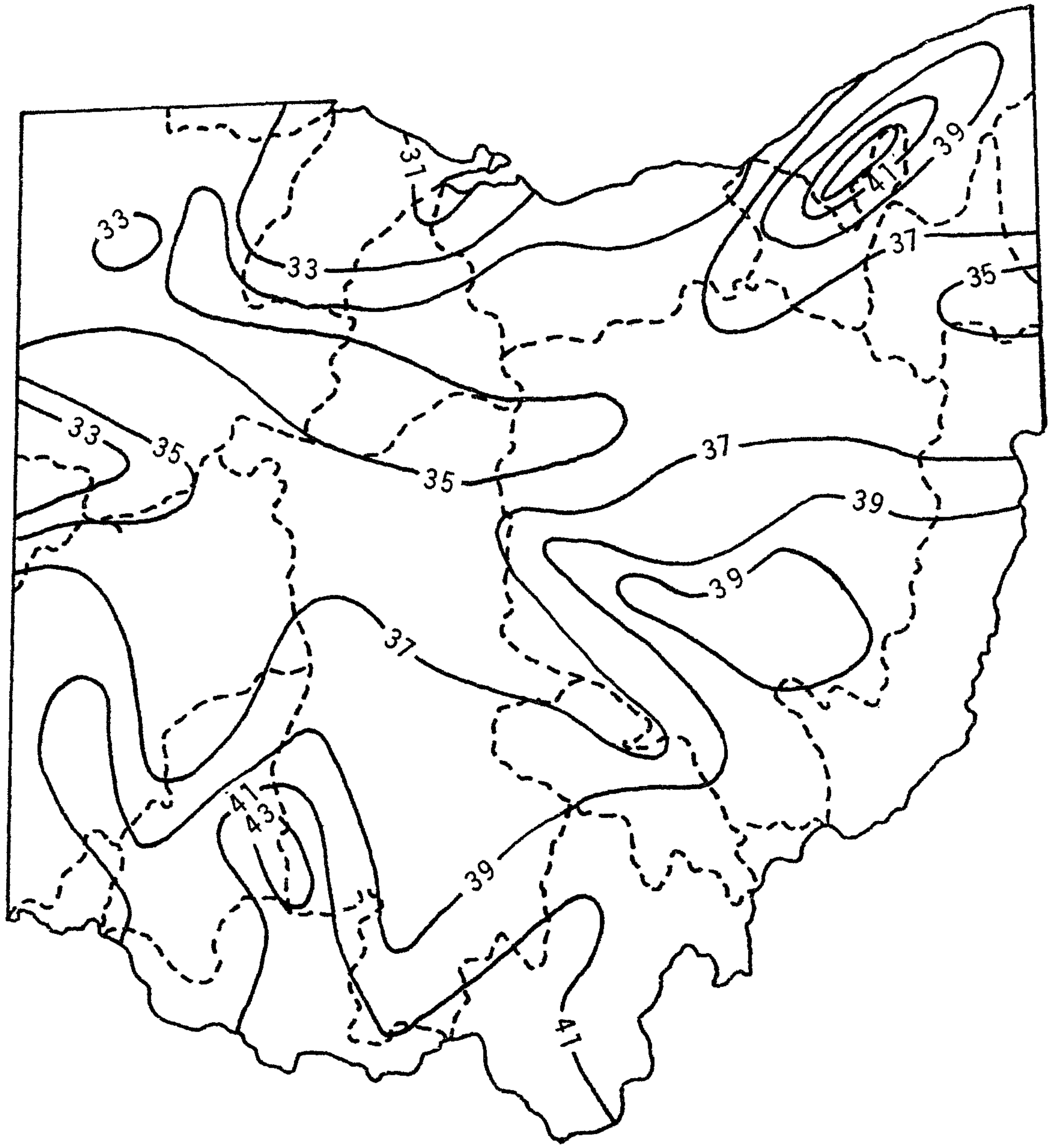



FIGURE 4-6. GENERALIZED MEAN ANNUAL PRECIPITATION (INCHES)

35 to 50 inches, respectively. The wettest season is during the summer when convectional storms supplement normal cyclonic depressions. Thunderstorms are slightly more common in the southern and western parts of Ohio, which accounts for the wide range in precipitation in that part of the state. During the years considered in this study, the least amount of precipitation was along the western end of Lake Erie. Bluffs near the Lake Erie shoreline, extending from Cleveland to the Pennsylvania border, in addition to the angle of the shoreline with respect to the prevailing winds, lead to orographic precipitation and consequently, a wide range in annual precipitation along the coast. Annual precipitation varies about 14 or 15 inches from the average in most regions of the state.

Much of the winter precipitation falls as snow. The high average in northeastern Ohio (more than 100 inches) is caused by the "lake effect" and the sweeping of moisture-laden winter winds over the escarpment of the Appalachian Plateaus.

Flooding in Ohio has been a significant aspect of many hydrological studies and many of the major streams are now regulated. Major widespread floods occurred in 1913 and 1959, but flooding occurs in some part of Ohio every year. The most widespread flooding occurs when extensive cyclonic depressions follow each other in quick succession and permit rain to fall on already saturated ground. Local flooding commonly occurs during the summer and these are related to convective storms. Flooding of this type is prevalent in the dissected Appalachian Plateau.

## Evapotranspiration

Evaporation rates vary widely, both seasonally and geographically (Wilson and Savage, 1936). Generalized average annual lake evaporation is illustrated in Figure 4-7. This map, one of a series of evaporation maps for the United

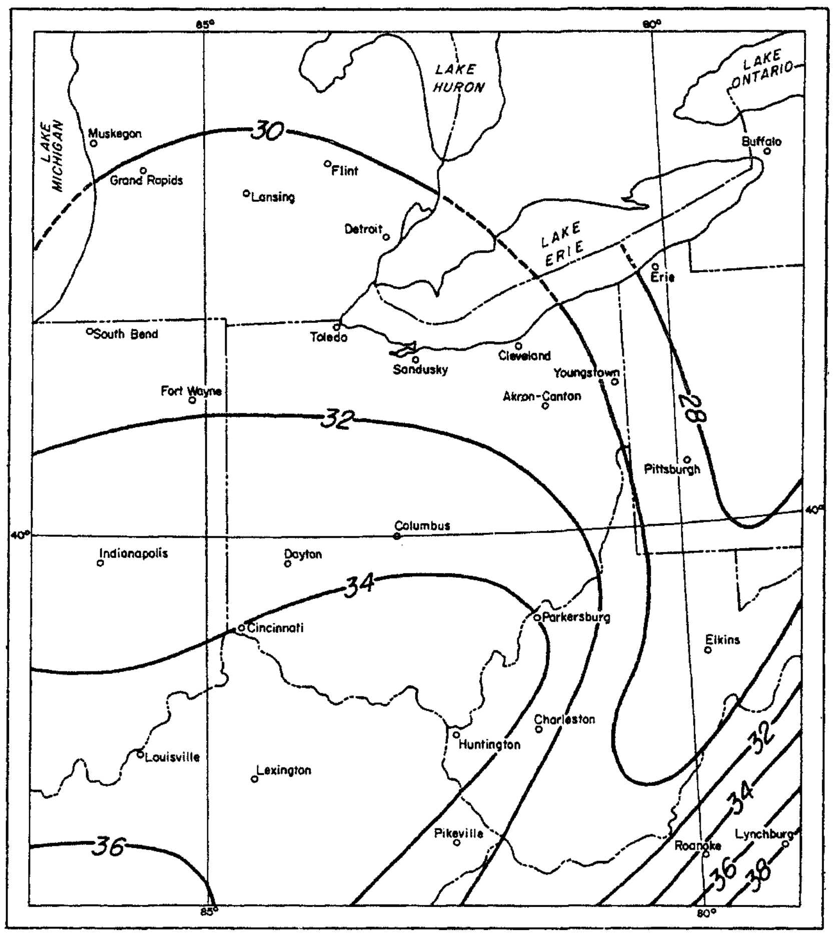



FIGURE 4-7. GENERALIZED AVERAGE ANNUAL LAKE EVAPORATION, IN INCHES

States, is based on pan records. The evaporation rates indicated by the map are maximum rates. Actual evaporation varies considerably and depends on many factors, including air temperature, wind movement, and atmospheric pressure. Since the atmosphere is a dynamic system, these factors do not long remain consistent and, therefore, evaporation varies widely both in time and space.

One of the most important causes of water loss from the ground is transpiration. This is the water returned to the atmosphere by plants. Evaporation and transpiration are collectively called evapotranspiration, or the total quantity of water transferred to the atmosphere from the land surface or near surface.

Transpiration has been extensively studied by agronomists in relation to consumptive use by different species of plants, and as evapotranspiration from different cultivation methods. Very little work has been published to indicate the relative areal extent of evapotranspiration on a regional basis in Ohio, but these losses certainly account for a substantial percentage of precipitation.

## Soils

Ohio soils exert important controls on infiltration because of their wide range in drainage characteristics. The general soil drainage characteristics aid in understanding the regional nature of ground-water recharge and dry-weather flow in Ohio (fig. 4-8). Other than induced infiltration from streambeds, much of the ground-water recharge depends on the characteristics of the soils. Poorly drained soils may indicate ground-water discharge areas and regions of substantial surface runoff. Well drained soils tend to allow water to infiltrate more readily and may account for a larger percentage of ground-water runoff. Most of the well drained soils occur in unglaciated regions of the state and in areas of outwash.

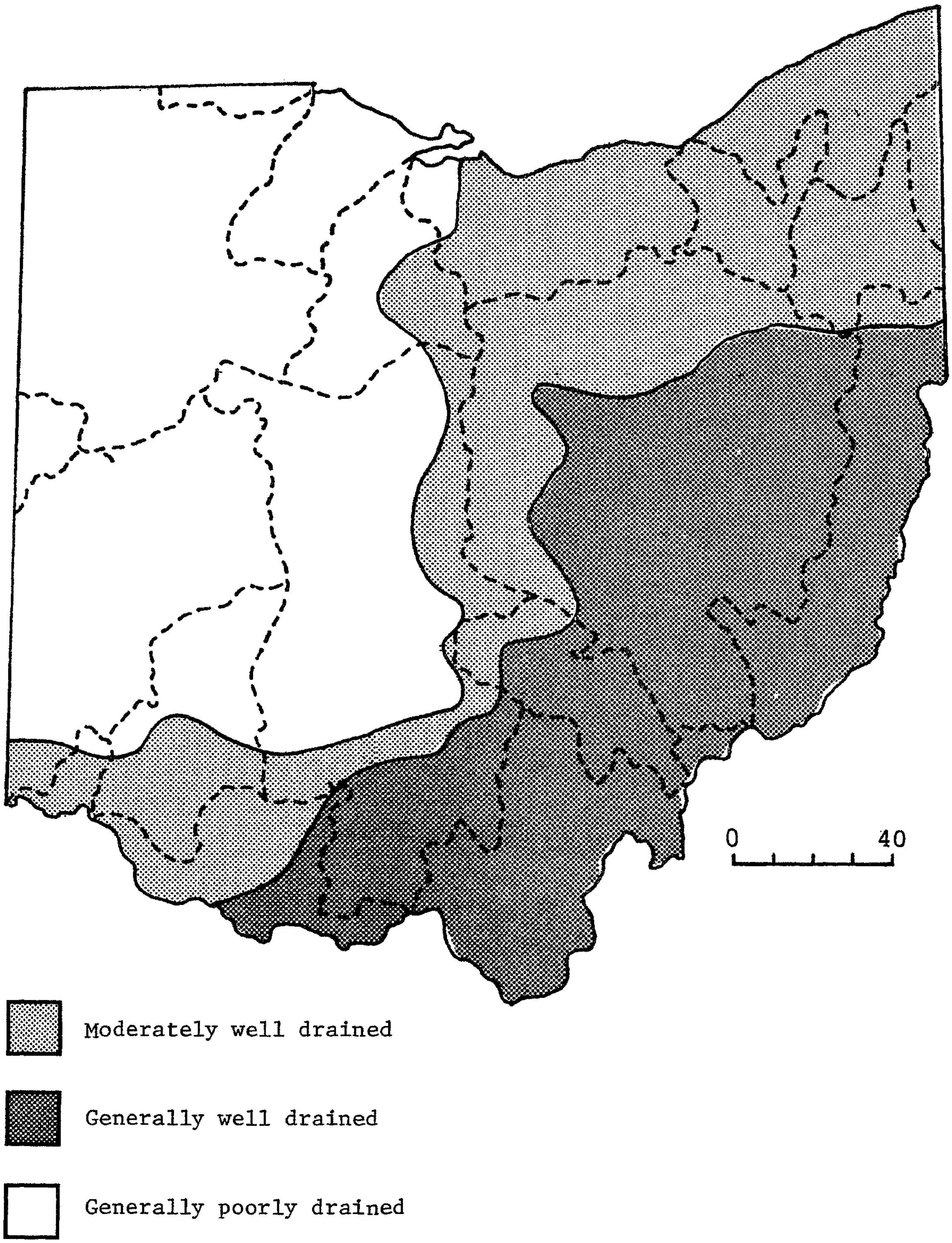



FIGURE 4-8. SOIL DRAINAGE CHARACTERISTICS

## Hydrogeology

Ground-water supplies are obtained from extensive outwash deposits, from a thick limestone sequence in northwestern Ohio, from relatively thin layers of sandstone in the eastern half of the state and from scattered lenses of sand and gravel within the till. Large yields are also derived from alluvial and outwash deposits along the Ohio River. Elsewhere small yields are obtained from thin layers of limestone, fractures in shale, and alluvium.

Ground-water runoff accounts for a variable amount of streamflow, ranging from less than 10 percent to perhaps as much as 75 percent or more. The amount of ground-water runoff is controlled largely by the permeability of near surface materials in the zone of active water circulation. There is no doubt that ground-water runoff from bedrock units covered by glacial deposits have some influence on streamflow, but presently the magnitude is unknown. Where available maps depicting the water table or potentiometric surface of bedrock aquifers covered by till or outwash show contours that extend a considerable distance up existing stream channels. Indicating that the aquifers are discharging into the streams.

In the surficial material, a ground-water divide extends east-west across the northern third of the state and generally follows the surface-water divide that separates the Lake Erie and Ohio River drainage basins. Within each sub-basin the ground-water divide also roughly conforms to the topographic divide. Ground-water divides within bedrock aquifers commonly have little relation to surface water basins as the flow is controlled largely by their permeability, structure and stratigraphy.

The water level in aquifers fluctuates throughout the year. In Ohio, the highest levels in surficial aquifers are generally reached in March and then decline throughout the year to reach a minimum in November. In bedrock aquifers the fluctuations are usually more subdued and, depending on the thickness and permeability of overlying units, the highs and lows may appear a month or two later.

An observation well tapping sand and gravel at Harrison indicates that the normal range in annual fluctuation is about 4 feet. A well in a sandstone aquifer at Windham and another in limestone at Kettlersville have maximum annual fluctuations of 2 and 1.5 feet, respectively. Despite the range in fluctuation throughout the year and from one year to the next, aquifers not influenced by high yield well fields are in equilibrium. That is, there is a long term balance between recharge and discharge. Short term perturbations brought about by intervals of unusually low or high precipitation certainly influence the system but the effects, within a year or two, return to normal.

The chemical quality of ground water in the zone of intensive movement is variable across the state, both vertically and horizontally. In light of the nature of the movement of water through porous media and the complex geochemistry of natural waters, only a rough approximation of regional changes in chemical quality can be estimated, but it is believed that a range of expected values is better than no information at all. For specific areas, local drillers and public health authorities can advise the consumer on the local range of values from different units at different depths and locations. The purpose of this study is not to define exact chemical relationships over a localized area, but merely to attempt to estimate the regional concentrations and changes in ground-water quality in the zone of active circulation.

Except in a few relatively small areas, the hardness of ground water used for drinking supplies in Ohio exceeds 100 mg/l. In the western half of the state where wells commonly produce from limestone aquifers, hardness generally exceeds 300 mg/l and in a few places it is more than 1000 mg/l. Water in outwash deposits, both in the glaciated and unglaciated regions, is usually hard enough to require treatment. Magnesium concentrations are usually consistent at 15 to 20 mg/l in the east and 25 to 30 mg/l in the west. Calcium ranges from as low as 15 mg/l to as much as 300 mg/l in the west. Sodium and potassium concentrations also increases westward, ranging from less than 10 mg/l in eastern counties to more than 170 mg/l in the Maumee basin. Throughout most of the state, chloride concentrations are less than 25 mg/l, but locally they approach 200 mg/l, particularly in areas of oil production. In some streamside aquifers, such as the Muskingum and Tuscarawas Rivers, chloride concentration in public supplies are related to high concentrations in the rivers, indicating infiltration through the streambed. Throughout most of Ohio, the concentration of sulfate in ground water is generally less than 250 mg/l; concentrations in excess of 100 mg/l are common in the eastern coal-mining regions and in the northwestern part of the state, where gypsum is common.

## Chapter 5

## REGIONAL GROUND-WATER RECHARGE RATES

The following effective ground-water recharge rate maps are based largely on data derived from stream hydrograph separations and flow-duration curves. Where these data were unavailable, estimates were obtained from geologic maps and from individual low-flow measurements reported by the U.S. Geological Survey. Many Ohio streams are regulated and, in most cases, hydrograph separation techniques produce results that are too high. The major regulated streams were not used in this study, except in some cases when it was possible to estimate recharge values on the basis of seepage measurements. In addition, some flow data for these streams were reported by Cross and Hedges (1959) and represent pre-controlled conditions. In some instances, baseflow before and after regulation was nearly identical.

It is assumed that the recharge rates determined during this study represent the average rate throughout the basin upstream from the gage. It is recognized, however, that this assumption is not entirely correct because geologic conditions can range widely throughout each basin. In fact, only in the Maumee Basin and the direct drainage into Lake Erie west of Cleveland are geologic conditions relatively uniform. Elsewhere, but particularly in the Muskingum, Scioto and Miami Basins, an abundance of permeable outwash occurs along the mainstem and many of its tributaries. In cases such as these, it is probable that much of the ground-water recharge occurs through these permeable deposits and the high rates of sustained flow are closely related to ground-water runoff from them. Nonetheless, part of the flow must be derived from less permeable and more distant parts of the basin. Additional study is needed along these lines.

It is likely that the recharge rate in areas such as these more closely reflect ground-water runoff from the more permeable deposits, but no exact relationship was determined during this study. Very probably the reported recharge fate, for example 300,000 to 400,000 gpd/sq.mi. along the Scioto River south of Columbus, is less than that which actually occurs in the areas of outwash, but is considerably higher than the rate in till covered areas.

The calculated high recharge rates in those basin tributaries to the Ohio River between East Liverpool and Portsmouth are the result of several phenomena. A few of the streams, such as Middle and North Fork Beaver Creek and Yellow Creek, contain permeable glacial deposits in their floodplains, which provide natural storage. In addition, precipitation along this reach exceeds 35 inches per year and is higher than many other areas in the State. The higher precipitation, coupled with the rugged topography and abundance of sandstone, provides a considerable amount of ground-water recharge, but apparently the storage is only of short duration. This assumption is supported by the relatively low 90 percent flow relative to quantity of recharge.

Another complicating factor is the effect on streamflow of an abundance of spoil materials derived from both strip and underground coal mining. The mines, largely because of the permeable nature of the spoil material, serve as large man-made storage reservoirs. Precipitation rapidly infiltrates the spoil in much the same manner as it does outwash. Furthermore, a larger percentage remains in the liquid state because of the smaller rate of evapotranspiration brought about by the low density cover of vegetation. Consequently, analysis of stream hydrographs in the coal mining areas of Ohio produce effective ground-water recharge rates that, from the regional viewpoint, are abnormally high. In cases such as these, recharge rates were based, to a large extent, on low-flow measurements.

In addition to a map, each basin has a series of tables that provide summary information about the geology and topography in the basin. Detailed information is provided for three representative gaging stations in each basin. The data include monthly recharge rates calculated by three different computer methods. FX indicates fixed interval separation, SL indicates sliding interval separation, and LM indicates local mimina separation.

All the station-years that have been used in this study are summarized in two other tables. The recharge rate table lists (1) the recharge rates as calculated by the fixed interval, the sliding interval, and local minima, (2) ground-water runoff as a percent of total runoff for each method, (3) the ground-water runoff, in inches as determined by each method, (4) total runoff, in inches, (5) the N interval and (6) the geology codes. The geology codes provide an approximation of the relief, surficial materials, and bedrock in the basin upstream from the station. Codes for this information are shown in Table 5-1.

The second table summarizes all the flow ratios and discharge percentages for all the station years considered. RT10/90 is the square root of the ratio of 10 percent to 90 percent flow, RT25/75 is the square root of the ratio of 25 to 75 percent flow, and Q95 through Q50 are the discharges, in cfs/sq. mi., that are equalled or exceeded 95 and 50 percent of the time. # MISSING is the number of days of missing record and NO FLOW indicates the number of days that no flow was recorded.

Care must be used when interpreting these tables. The information listed is presented exactly as returned as computer output. Factors such as precipitation, regulation, and missing record, or no flow should be scrutinized. This information is only a guide to particular stream characteristics. For a specific area, a long period of record should be digitized and analyzed to

RELIEF

| | |
|---|---|
| 1 | Low |
| 2 | Moderate |
| 3 | High |

BEDROCK

| | |
|---|---|
| 1 | Sandstone, Shale, Coal (Permian, Penn) |
| 2 | Sandstone & Shale (Miss.) |
| 3 | Shale (Devonian) |
| 4 | Limestone & Dolomite (Silurian) |
| 5 | Shale & Limestone (Ordovician) |

SURFICIAL DEPOSITS

| | |
|---|---|
| 10 | Till |
| | Ground Moraine |
| 11 | Thin |
| 12 | Thick |
| 13 | End Moraine |
| 20 | Outwash |
| 21 | Surficial Outwash |
| 22 | Buried Outwash |
| 30 | Lake Plain |
| 90 | Other (Unglaciated) |

TABLE 5-1. TOPOGRAPHIC AND GEOLOGIC CODES

determine average long-term values and trends. The purpose of this report is to estimate regional trends and not provide exact information on specific stations.

## Maumee River Basin

The Maumee River originates in Ft. Wayne, Indiana, at the confluence of the St. Joseph and St. Marys River (Fig. 5-1). The drainage basin consists of 6586 square miles, of which 1260 are in northeastern Indiana, and 470 lie in south-central Michigan. The Maumee River stretches about 150 miles from Ft. Wayne to Toledo when it empties into Lake Erie. It has a gradient of about 1.1 feet per mile.

The St. Joseph River, which drains about 1060 square miles, originates in Hillsdale County, Michigan, in a rolling till plain region and flows southeastward for about 100 miles between the westerly Wabash and the easterly Ft. Wayne Moraines. The St. Marys River, which has its headwaters in Auglaize and Shelby Counties, Ohio, flows generally northwestward in a broad arc to join the St. Joseph at Ft. Wayne. The St. Marys is also about 100 miles long. Other major tributaries to the Maumee includes Tiffin River and Bad Creek, which flow southward and the Auglaize River, which originates along a divide that forms the southern part of the basin. In contrast to streams in the north, the Auglaize is fed by several tributaries, including Town Creek, and the Little Auglaize, Ottawa and Blanchard Rivers.

Silurian, Devonian and Mississippian age rocks underlie the basin and locally crop out. Consisting largely of carbonates, Silurian and Devonian rocks generally subcrop beneath a layer of till that is usually less than 30 feet and commonly less than 10 feet thick. The volume of ground water discharging directly from these deposits into streams is probably small. Mississippian age shale and sandstone underlie the northwestern part of the basin and ground-water runoff from

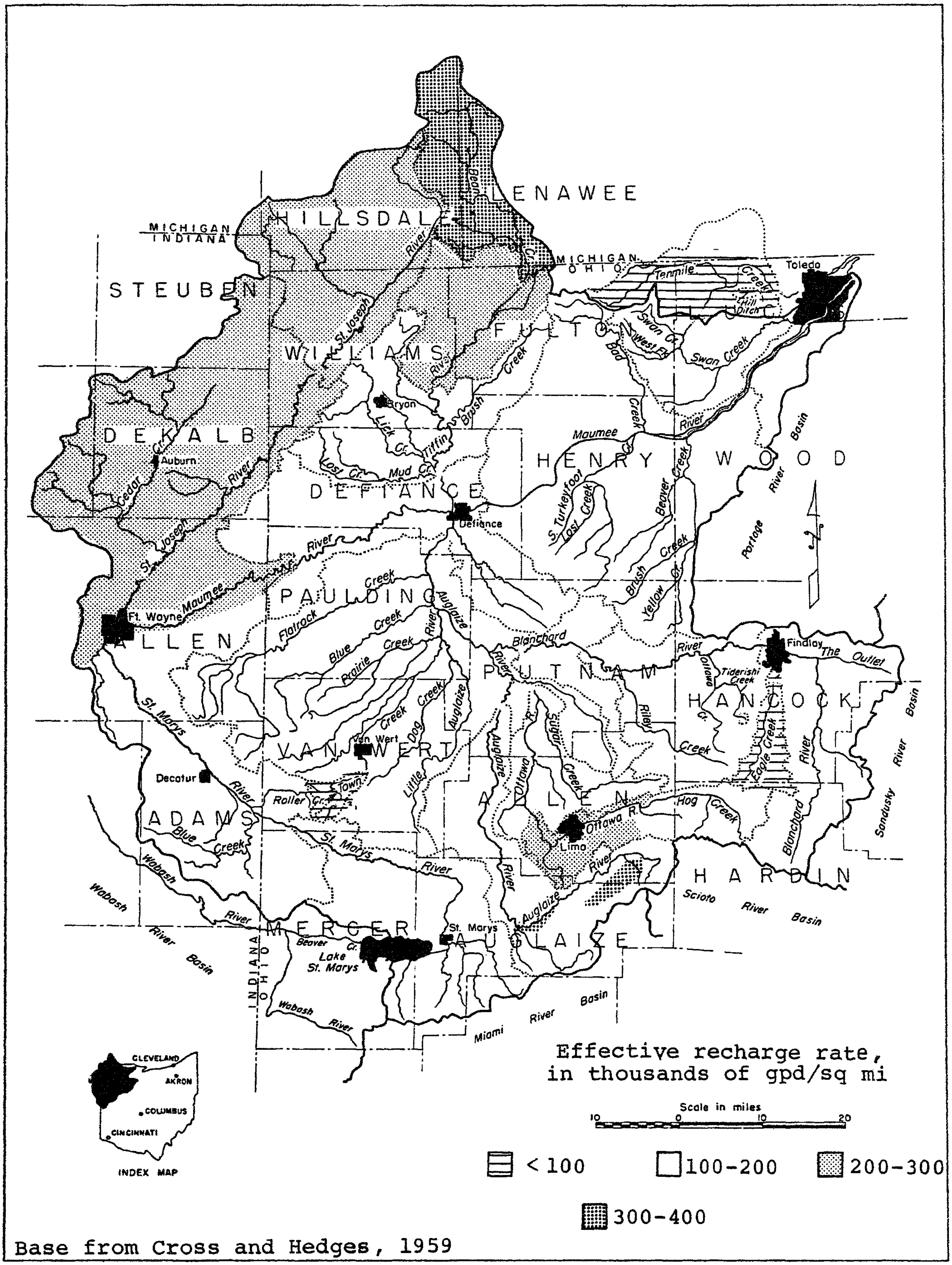



FIGURE 5-1. EFFECTIVE RECHARGE RATES IN THE MAUMEE RIVER BASIN

them is probably insignificant.

Covering the Paleozoic bedrock is glacial till and lake sediments. End moraines, a mile or two wide, are hummocky and rise a few feet above the low relief ground moraine. The glacial till consists largely of clay, but lenses of sand and gravel are common in end moraines, although less so in ground moraine. In the central part of the basin lies the nearly flat sand, silt and clay deposits formed in and along glacial Lake Maumee. These fine-grained deposits are only slightly permeable, in contrast to the numerous sandy beach ridges. The beach ridges are only a few feet thick. Along some of the streams, such as the St. Joseph River, are sand and gravel deposits, generally covered by a thin layer of till or alluvium, that have a significant effect on dry-weather flow.

Although their general courses are not well defined, several deep valleys were cut into the underlying bedrock during pre-glacial periods. Most are now filled with sand and gravel or till and their paths are totally obscured. Some preliminary data indicate that stream flow increases where modern day waterways cross these buried valleys. This indicates an upward component of groundwater flow.

Most of the Maumee Basin is nearly flat, especially in the Lake Plans regions. End moraines, particularly those in the northwest, are hummocky and rise a few feet above the surrounding low relief ground moraine.

Annual average precipitation in the basin is about 36 inches in the southwest corner and it decreases northward to less than 32 inches in the Toledo area. Regional patterns differ, however, from one year to the next (Figs. 5-2, 5-3, 5-4). During water year 1963, precipitation ranged from a high of about 30 inches in the northwest corner (Fig. 5-2). Precipitation ranged from a little more than 35 inches in the southcentral part of the basin to less than

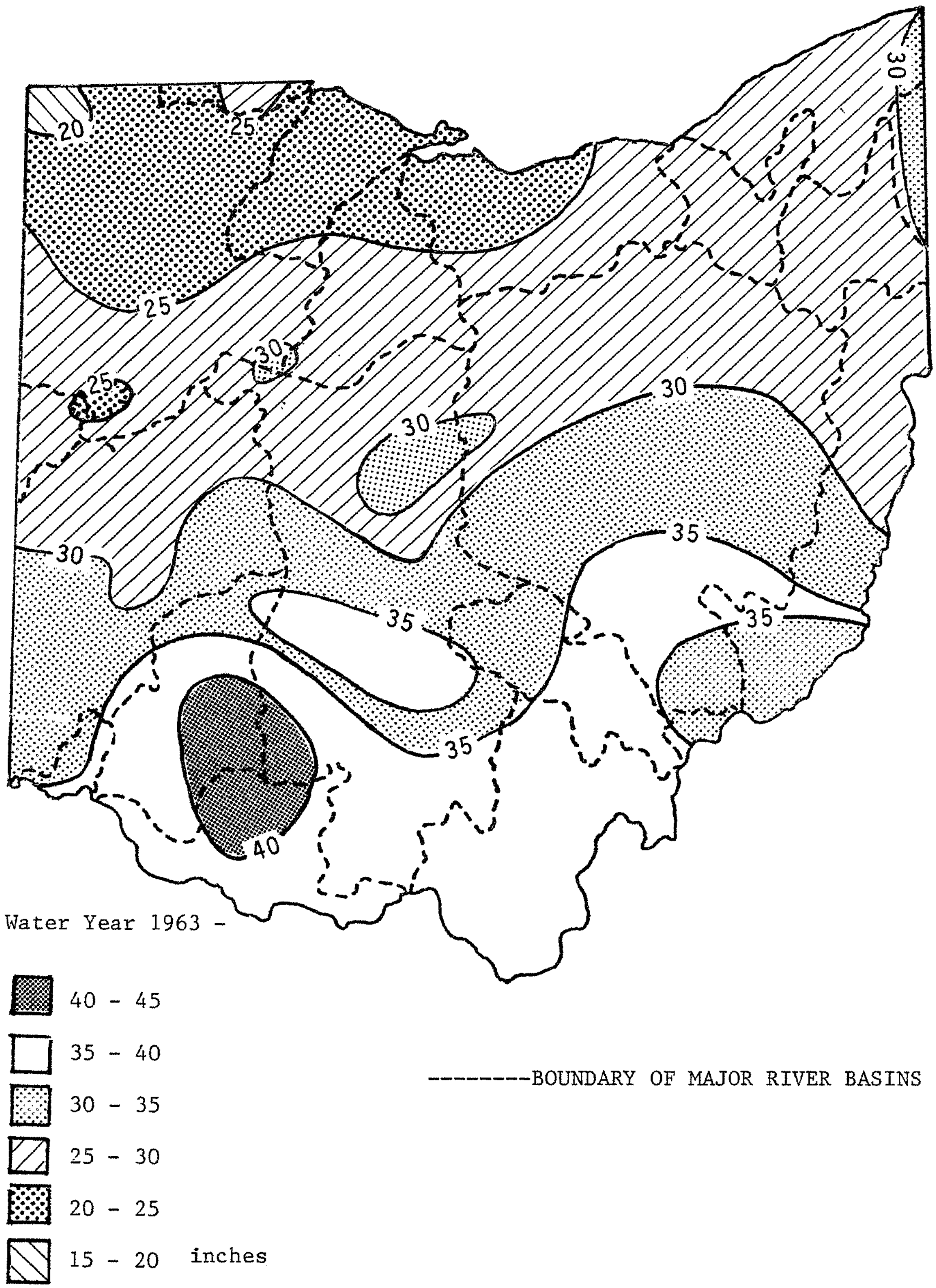



FIGURE 5-2. PRECIPITATION DURING WATER YEAR 1963 IN OHIO

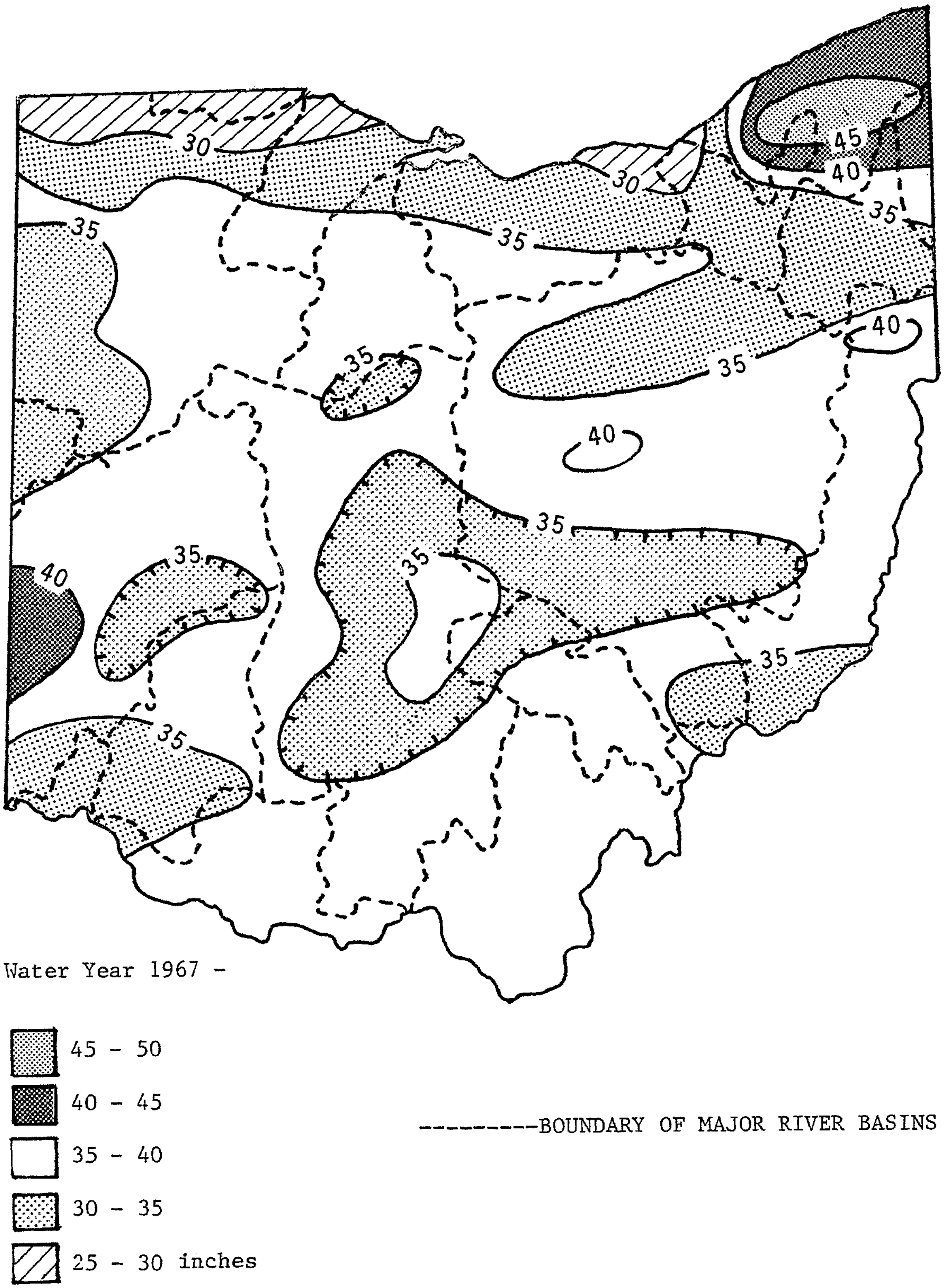



FIGURE 5-3. PRECIPITATION DURING WATER YEAR 1967 IN OHIO

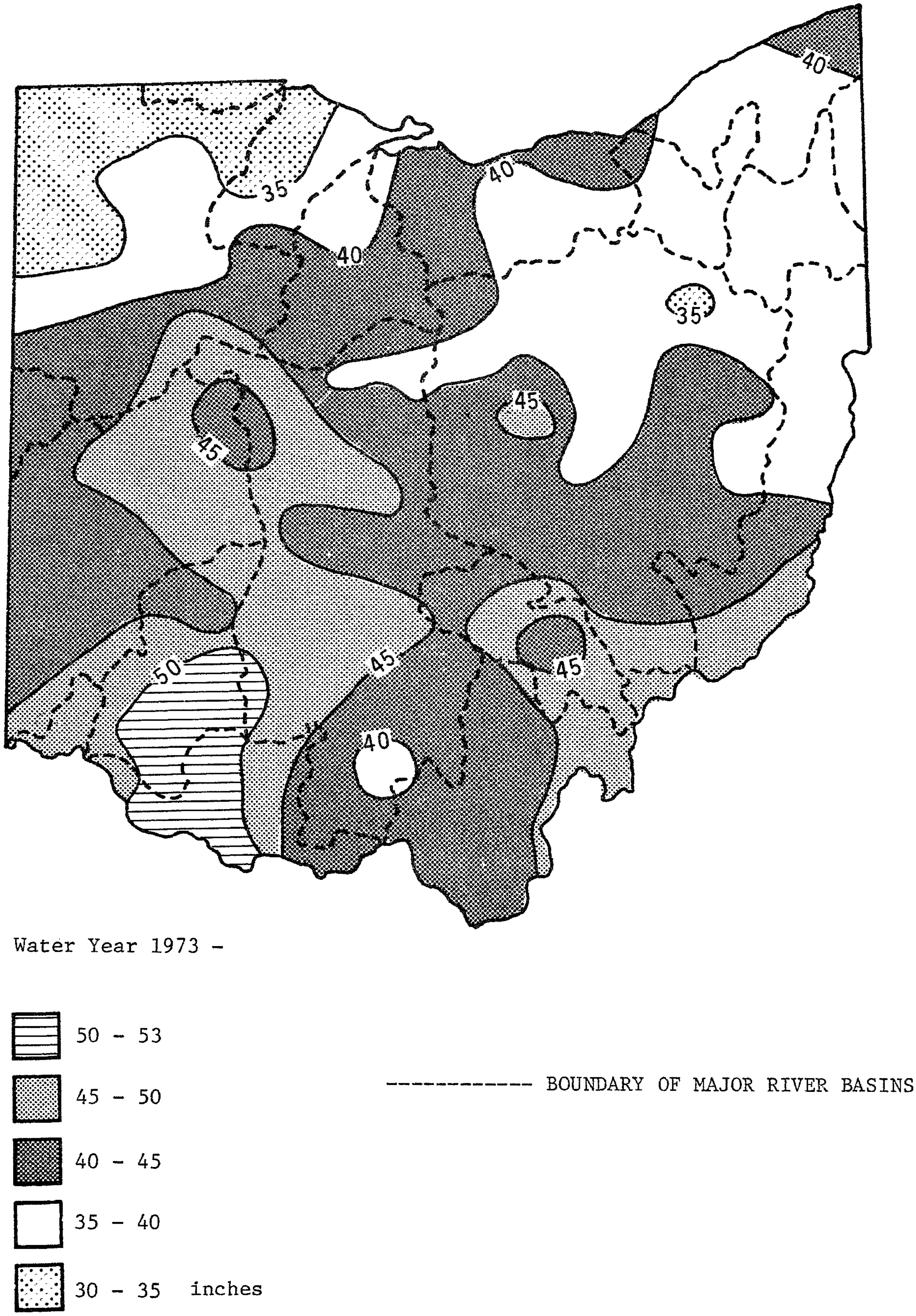



FIGURE 5-4. PRECIPITATION DURING WATER YEAR 1973 IN OHIO

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4178000 ST. JOSEPH RIVER NEAR NEWVILLE, IND. | | | | | | | | | | | | | | |
| 63 | 137000. | 150000. | 101000. | 64. | 70. | 47. | 2.89 | 3.15 | 2.13 | 4.49 | 3.61 | 1 | 21 | 3 |
| 67 | 314000. | 312000. | 236000. | 65. | 65. | 49. | 6.60 | 6.56 | 4.97 | 10.16 | 3.61 | 1 | 21 | 3 |
| 73 | 571000. | 566000. | 505000. | 72. | 71. | 63. | 12.00 | 11.90 | 10.61 | 16.73 | 3.61 | 1 | 21 | 3 |
| 4181500 ST. MARYS RIVER AT DECATUR, IND. | | | | | | | | | | | | | | |
| 63 | 120000. | 128000. | 91000. | 49. | 53. | 37. | 2.54 | 2.70 | 1.92 | 5.14 | 3.62 | 1 | 21 | 4 |
| 67 | 264000. | 265000. | 189000. | 47. | 47. | 34. | 5.56 | 5.57 | 3.98 | 11.85 | 3.62 | 1 | 21 | 4 |
| 73 | 477000. | 492000. | 364000. | 55. | 57. | 42. | 10.03 | 10.35 | 7.66 | 18.10 | 3.62 | 1 | 21 | 4 |
| 4183000 MAUMEE RIVER AT NEW HAVEN, IND. | | | | | | | | | | | | | | |
| 63 | 114000. | 127000. | 127000. | 52. | 58. | 58. | 2.41 | 2.67 | 2.67 | 4.62 | 4.56 | 1 | 10 | 4 |
| 67 | 276000. | 293000. | 293000. | 47. | 50. | 50. | 5.82 | 6.16 | 6.16 | 12.36 | 4.56 | 1 | 10 | 4 |
| 73 | 529000. | 518000. | 521000. | 61. | 59. | 60. | 11.12 | 10.90 | 10.96 | 18.33 | 4.56 | 1 | 10 | 4 |
| 4183500 MAUMEE RIVER AT ANTWERP, OHIO | | | | | | | | | | | | | | |
| 63 | 113000. | 126000. | 127000. | 53. | 59. | 59. | 2.39 | 2.67 | 2.67 | 4.54 | 4.63 | 1 | 10 | 3 |
| 67 | 271000. | 291000. | 291000. | 46. | 49. | 49. | 5.71 | 6.12 | 6.13 | 12.43 | 4.63 | 1 | 10 | 3 |
| 73 | 510000. | 498000. | 501000. | 61. | 60. | 60. | 10.72 | 10.46 | 10.54 | 17.46 | 4.63 | 1 | 10 | 3 |
| 4184500 BEAN CREEK AT POWERS, OHIO | | | | | | | | | | | | | | |
| 63 | 128000. | 128000. | 116000. | 77. | 77. | 70. | 2.70 | 2.69 | 2.46 | 3.50 | 2.90 | 1 | 30 | 2 |
| 67 | 359000. | 380000. | 327000. | 65. | 69. | 59. | 7.55 | 8.00 | 6.87 | 11.61 | 2.90 | 1 | 30 | 2 |
| 73 | 541000. | 546000. | 503000. | 72. | 73. | 67. | 11.37 | 11.47 | 10.57 | 15.70 | 2.90 | 1 | 30 | 2 |

TABLE 5-2. RECHARGE STATISTICS FOR THE MAUMEE RIVER BASIN

TABLE 5-2 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4185000 TIFFIN RIVER AT STRYKER, OHIO | | | | | | | | | | | | | | |
| 63 | 91000. | 96000. | 62000. | 63. | 66. | 43. | 1.92 | 2.02 | 1.32 | 3.06 | 3.33 | 1 | 30 | 2 |
| 67 | 332000. | 339000. | 274000. | 63. | 64. | 52. | 6.99 | 7.13 | 5.77 | 11.18 | 3.33 | 1 | 30 | 2 |
| 73 | 477000. | 476000. | 421000. | 65. | 65. | 57. | 10.04 | 10.00 | 8.85 | 15.48 | 3.33 | 1 | 30 | 2 |
| 4186500 AUGLAIZE RIVER NEAR FORT JENNINGS, OHIO | | | | | | | | | | | | | | |
| 63 | 99000. | 123000. | 88000. | 32. | 40. | 29. | 2.10 | 2.58 | 1.86 | 6.47 | 3.19 | 1 | 30 | 4 |
| 67 | 216000. | 232000. | 196000. | 34. | 37. | 31. | 4.56 | 4.88 | 4.13 | 13.25 | 3.19 | 1 | 30 | 4 |
| 73 | 387000. | 402000. | 395000. | 36. | 37. | 37. | 8.15 | 8.44 | 8.32 | 22.61 | 3.19 | 1 | 30 | 4 |
| 4187500 OTTAWA RIVER AT ALLENTOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 144000. | 136000. | 114000. | 50. | 47. | 39. | 3.04 | 2.86 | 2.40 | 6.12 | 2.76 | 1 | 21 | 4 |
| 67 | 263000. | 288000. | 219000. | 36. | 39. | 30. | 5.54 | 6.06 | 4.60 | 15.59 | 2.76 | 1 | 21 | 4 |
| 73 | 438000. | 443000. | 417000. | 40. | 40. | 38. | 9.20 | 9.31 | 8.78 | 23.23 | 2.76 | 1 | 21 | 4 |
| 4189000 BLANCHARD RIVER NEAR FINDLAY, OHIO | | | | | | | | | | | | | | |
| 63 | 101000. | 114000. | 105000. | 32. | 36. | 33. | 2.14 | 2.41 | 2.22 | 6.71 | 3.22 | 1 | 21 | 4 |
| 67 | 184000. | 207000. | 157000. | 28. | 31. | 24. | 3.87 | 4.36 | 3.30 | 13.87 | 3.22 | 1 | 21 | 4 |
| 73 | 390000. | 384000. | 387000. | 37. | 36. | 36. | 8.19 | 8.08 | 8.13 | 22.40 | 3.22 | 1 | 21 | 4 |
| 4191500 AUGLAIZE RIVER NEAR DEFIANCE, OHIO | | | | | | | | | | | | | | |
| 63 | 69000. | 79000. | 79000. | 33. | 37. | 37. | 1.46 | 1.66 | 1.66 | 4.46 | 4.71 | 1 | 30 | 3 |
| 67 | 166000. | 191000. | 191000. | 24. | 27. | 28. | 3.50 | 4.02 | 4.03 | 14.64 | 4.71 | 1 | 30 | 3 |
| 73 | 369000. | 353000. | 369000. | 40. | 38. | 40. | 7.77 | 7.42 | 7.77 | 19.53 | 4.71 | 1 | 30 | 3 |

TABLE 5-2 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4192500 MAUMEE RIVER NEAR DEFIANCE, OHIO | | | | | | | | | | | | | | |
| 63 | 66000. | 90000. | 90000. | 33. | 46. | 46. | 1.39 | 1.90 | 1.91 | 4.18 | 5.61 | 1 | 30 | 3 |
| 67 | 211000. | 212000. | 212000. | 35. | 36. | 36. | 4.45 | 4.47 | 4.47 | 12.55 | 5.61 | 1 | 30 | 3 |
| 73 | 411000. | 410000. | 421000. | 47. | 47. | 48. | 8.65 | 8.63 | 8.86 | 18.49 | 5.61 | 1 | 30 | 3 |
| 4193500 MAUMEE RIVER AT WATERVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 70000. | 90000. | 91000. | 35. | 45. | 45. | 1.49 | 1.91 | 1.91 | 4.28 | 5.76 | 1 | 30 | 4 |
| 67 | 222000. | 228000. | 228000. | 34. | 35. | 35. | 4.66 | 4.80 | 4.80 | 13.67 | 5.76 | 1 | 30 | 4 |
| 73 | 407000. | 407000. | 420000. | 47. | 47. | 49. | 8.57 | 8.57 | 8.83 | 18.17 | 5.76 | 1 | 30 | 4 |

MAUMEE BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 4178000 ST. JOSEPH RIVER NEAR NEWVILLE, IND. | | | | | | | | | | | | |
| FX | 44000. | 51000. | 48000. | 38000. | 39000. | 835000. | 258000. | 132000. | 81000. | 48000. | 38000. | 20000. |
| SL | 44000. | 51000. | 48000. | 39000. | 40000. | 961000. | 264000. | 134000. | 83000. | 56000. | 38000. | 20000. |
| LM | 45000. | 51000. | 47000. | 39000. | 42000. | 378000. | 284000. | 137000. | 63000. | 67000. | 33000. | 20000. |
| 67 | | | | | | | | | | | | |
| FX | 24000. | 93000. | 811000. | 202000. | 325000. | 1087000. | 711000. | 272000. | 124000. | 55000. | 28000. | 23000. |
| SL | 24000. | 94000. | 772000. | 228000. | 339000. | 1048000. | 724000. | 279000. | 123000. | 56000. | 27000. | 23000. |
| LM | 22000. | 70000. | 166000. | 193000. | 276000. | 896000. | 731000. | 257000. | 123000. | 57000. | 28000. | 21000. |
| 73 | | | | | | | | | | | | |
| FX | 225000. | 841000. | 686000. | 780000. | 413000. | 1513000. | 762000. | 481000. | 667000. | 304000. | 109000. | 54000. |
| SL | 252000. | 918000. | 658000. | 704000. | 419000. | 1487000. | 730000. | 464000. | 686000. | 302000. | 111000. | 53000. |
| LM | 218000. | 859000. | 659000. | 520000. | 380000. | 1381000. | 719000. | 392000. | 473000. | 282000. | 110000. | 57000. |
| 63 4184500 BEAN CREEK AT POWERS, OHIO | | | | | | | | | | | | |
| FX | 49000. | 64000. | 51000. | 43000. | 45000. | 505000. | 395000. | 186000. | 110000. | 41000. | 26000. | 19000. |
| SL | 50000. | 65000. | 51000. | 43000. | 44000. | 520000. | 368000. | 191000. | 111000. | 37000. | 25000. | 19000. |
| LM | 49000. | 64000. | 49000. | 44000. | 44000. | 448000. | 330000. | 190000. | 93000. | 36000. | 26000. | 19000. |
| 67 | | | | | | | | | | | | |
| FX | 55000. | 174000. | 674000. | 402000. | 407000. | 892000. | 1055000. | 328000. | 121000. | 100000. | 60000. | 42000. |
| SL | 54000. | 169000. | 759000. | 376000. | 422000. | 1060000. | 1075000. | 329000. | 119000. | 103000. | 60000. | 39000. |
| LM | 55000. | 111000. | 567000. | 332000. | 370000. | 721000. | 1141000. | 317000. | 118000. | 95000. | 61000. | 39000. |
| 73 | | | | | | | | | | | | |
| FX | 181000. | 710000. | 653000. | 697000. | 414000. | 1439000. | 701000. | 707000. | 565000. | 252000. | 108000. | 49000. |
| SL | 187000. | 721000. | 670000. | 740000. | 403000. | 1553000. | 689000. | 641000. | 528000. | 240000. | 105000. | 49000. |
| LM | 152000. | 700000. | 643000. | 797000. | 372000. | 1407000. | 687000. | 375000. | 500000. | 238000. | 98000. | 50000. |
| 63 4189000 BLANCHARD RIVER NEAR FINDLAY, OHIO | | | | | | | | | | | | |
| FX | 22000. | 40000. | 42000. | 42000. | 52000. | 651000. | 188000. | 72000. | 42000. | 22000. | 20000. | 14000. |
| SL | 23000. | 41000. | 43000. | 43000. | 50000. | 805000. | 183000. | 71000. | 42000. | 22000. | 20000. | 14000. |
| LM | 21000. | 39000. | 40000. | 40000. | 45000. | 729000. | 177000. | 70000. | 33000. | 23000. | 21000. | 14000. |
| 67 | | | | | | | | | | | | |
| FX | 27000. | 105000. | 339000. | 118000. | 214000. | 581000. | 358000. | 243000. | 80000. | 49000. | 50000. | 40000. |
| SL | 27000. | 141000. | 522000. | 106000. | 222000. | 510000. | 364000. | 363000. | 78000. | 62000. | 47000. | 36000. |
| LM | 26000. | 75000. | 208000. | 117000. | 200000. | 478000. | 358000. | 197000. | 72000. | 60000. | 60000. | 33000. |
| 73 | | | | | | | | | | | | |
| FX | 228000. | 710000. | 604000. | 286000. | 206000. | 1203000. | 540000. | 293000. | 312000. | 170000. | 69000. | 38000. |
| SL | 237000. | 736000. | 650000. | 277000. | 215000. | 1096000. | 532000. | 298000. | 304000. | 138000. | 74000. | 38000. |
| LM | 193000. | 782000. | 614000. | 343000. | 207000. | 1126000. | 501000. | 284000. | 313000. | 162000. | 62000 | 38000. |

TABLE 5-3. MONTHLY RECHARGE RATES FOR THE MAUMEE RIVER BASIN

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 4178000 ST. JOSEPH RIVER NEAR NEWVILLE, IND. | | | | | | | | | |
| 63 | 3.96922 | 1.98370 | 0.03448 | 0.04351 | 0.06322 | 0.07718 | 0.08374 | 0 | 0 |
| 67 | 7.08519 | 3.81361 | 0.03612 | 0.04105 | 0.06117 | 0.18227 | 0.29557 | 0 | 0 |
| 73 | 4.30495 | 2.01197 | 0.08852 | 0.15082 | 0.46066 | 0.77049 | 0.96721 | 0 | 0 |
| 4181500 ST. MARYS RIVER AT DECATUR, IND. | | | | | | | | | |
| 63 | 5.89413 | 2.35250 | 0.01932 | 0.02174 | 0.02939 | 0.03704 | 0.05153 | 0 | 0 |
| 67 | 11.57275 | 5.05964 | 0.02093 | 0.02254 | 0.03221 | 0.08696 | 0.15459 | 0 | 0 |
| 73 | 5.93381 | 2.67425 | 0.04992 | 0.09581 | 0.26288 | 0.45250 | 0.72061 | 0 | 0 |
| 4183000 MAUMEE RIVER AT NEW HAVEN, IND. | | | | | | | | | |
| 63 | 4.38392 | 1.94759 | 0.03866 | 0.04883 | 0.05900 | 0.06714 | 0.07731 | 0 | 0 |
| 67 | 7.48848 | 3.95341 | 0.04273 | 0.04603 | 0.07070 | 0.17650 | 0.29069 | 0 | 0 |
| 73 | 3.76144 | 1.97471 | 0.08693 | 0.20895 | 0.47293 | 0.73716 | 1.02949 | 0 | 0 |
| 4183500 MAUMEE RIVER AT ANTWERP, OHIO | | | | | | | | | |
| 63 | 4.17347 | 1.95773 | 0.04417 | 0.05005 | 0.06109 | 0.07143 | 0.08365 | 0 | 0 |
| 67 | 7.34255 | 3.53754 | 0.04323 | 0.04864 | 0.08271 | 0.17528 | 0.32378 | 0 | 0 |
| 73 | 3.95366 | 1.90985 | 0.09629 | 0.18225 | 0.47440 | 0.72334 | 0.97229 | 0 | 0 |
| 4184500 BEAN CREEK AT POWERS, OHIO | | | | | | | | | |
| 63 | 3.61421 | 1.70460 | 0.03398 | 0.03883 | 0.06432 | 0.07282 | 0.09223 | 0 | 0 |
| 67 | 5.68624 | 2.65797 | 0.06796 | 0.07282 | 0.13107 | 0.24272 | 0.40777 | 0 | 0 |
| 73 | 4.77124 | 2.19024 | 0.08252 | 0.12379 | 0.34102 | 0.58252 | 0.83252 | 0 | 0 |

TABLE 5-4. FLOW-RATIO STATISTICS FOR THE MAUMEE RIVER BASIN

TABLE 5-4 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 4185000 TIFFIN RIVER AT STRYKER, OHIO | | | | | | | | | |
| 63 | 4.40454 | 1.92124 | 0.02195 | 0.02439 | 0.04146 | 0.04878 | 0.06098 | 0 | 0 |
| 67 | 7.11928 | 3.39815 | 0.03902 | 0.04634 | 0.08354 | 0.18293 | 0.30488 | 0 | 0 |
| 73 | 6.27250 | 2.50036 | 0.05122 | 0.07439 | 0.25183 | 0.55366 | 0.73171 | 0 | 0 |
| 4186500 AUGLAIZE RIVER NEAR FORT JENNINGS, OHIO | | | | | | | | | |
| 63 | 4.53557 | 2.00000 | 0.03916 | 0.04217 | 0.05422 | 0.06627 | 0.07831 | 0 | 0 |
| 67 | 6.49145 | 3.39725 | 0.04518 | 0.05422 | 0.08208 | 0.15060 | 0.26205 | 0 | 0 |
| 73 | 5.29347 | 2.47487 | 0.09036 | 0.14458 | 0.30120 | 0.55120 | 0.86145 | 0 | 0 |
| 4187500 OTTAWA RIVER AT ALLENTOWN, OHIO | | | | | | | | | |
| 63 | 2.16251 | 1.29099 | 0.10000 | 0.10625 | 0.11250 | 0.12500 | 0.13125 | 0 | 0 |
| 67 | 4.39614 | 2.15728 | 0.13750 | 0.14375 | 0.16250 | 0.18750 | 0.25312 | 0 | 0 |
| 73 | 4.78910 | 2.62409 | 0.16250 | 0.19375 | 0.28750 | 0.46875 | 0.64687 | 0 | 0 |
| 4189000 BLANCHARD RIVER NEAR FINDLAY, OHIO | | | | | | | | | |
| 63 | 5.36656 | 1.88746 | 0.02601 | 0.02890 | 0.04624 | 0.06647 | 0.07514 | 0 | 0 |
| 67 | 6.75626 | 2.96444 | 0.04624 | 0.04913 | 0.09538 | 0.16763 | 0.24855 | 0 | 0 |
| 73 | 6.13572 | 2.54283 | 0.06647 | 0.09827 | 0.28685 | 0.47110 | 0.71965 | 0 | 0 |
| 4191500 AUGLAIZE RIVER NEAR DEFIANCE, OHIO | | | | | | | | | |
| 63 | 8.91227 | 2.86138 | 0.00475 | 0.00755 | 0.01726 | 0.03538 | 0.05220 | 0 | 0 |
| 67 | 10.43831 | 4.34372 | 0.02675 | 0.03106 | 0.05145 | 0.13028 | 0.23663 | 0 | 0 |
| 73 | 7.22871 | 2.56577 | 0.04271 | 0.07463 | 0.27998 | 0.51337 | 0.79163 | 0 | 0 |

TABLE 5-4 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 4192500 MAUMEE RIVER NEAR DEFIANCE, OHIO | | | | | | | | | |
| 63 | 5.25554 | 2.19792 | 0.02074 | 0.02615 | 0.03626 | 0.04563 | 0.05979 | 0 | 0 |
| 67 | 9.03248 | 4.23463 | 0.03102 | 0.03526 | 0.05975 | 0.15133 | 0.24351 | 0 | 0 |
| 73 | 5.53825 | 2.32509 | 0.05482 | 0.10730 | 0.37196 | 0.59152 | 0.93778 | 0 | 0 |
| 4193500 MAUMEE RIVER AT WATERVILLE, OHIO | | | | | | | | | |
| 63 | 5.57178 | 2.21565 | 0.02228 | 0.02647 | 0.03476 | 0.04298 | 0.05870 | 0 | 0 |
| 67 | 9.86625 | 4.05754 | 0.02781 | 0.03271 | 0.06680 | 0.16274 | 0.26702 | 0 | 0 |
| 73 | 5.16189 | 2.27778 | 0.05608 | 0.12243 | 0.37757 | 0.59084 | 0.83333 | 0 | 0 |

30 inches along the northern border during water year 1967 and from a low of about 30 inches near the northwest corner to a high of about 50 inches in the southern part of the basin during the 1973 water year. Both the amount and pattern of precipitation have significant effects on streamflow and ground-water recharge.

As a general rule, throughout the Maumee Basin stream flow is usually highest during March and April and lowest during August and September. Following the pattern of precipitation, average annual streamflow decreases from about 11 inches in the southwest to less than 8 inches in the northeast.

The chemical quality of ground-water in the basin is relatively poor due to high concentrations of dissolved solids, hardness, and, locally, sulfate. Furthermore, many streams are contaminated because of waste disposal. In general, chloride concentrations are less than 25 mg/l, sulfate less than 175 and dissolved solids range from 300 to 800 and hardness from 350 to 700 mg/l. Water in the zone of intensive circulation (glacial deposits) is generally less mineralized than that in bedrock aquifers.

In the upper two thirds of the St. Joseph River basin, bedrock consists predominantly of shale and a small amount of sandstone of Mississippian age. In the lower part of the basin bedrock becomes progressively older, from Devonian to Silurian, and consists almost entirely of limestone. Throughout the basin, however, the cover of glacial till is so thick that ground-water runoff from the bedrock is insignificant relative to the volume of ground-water runoff originating from the glacial material.

Thick deposits of glacial till and outwash mantle the entire region. West of the river these deposits, largely in the form of the Wabash Moraine, exceed 325 feet in thickness, while to the southeast (Fort Wayne Moraine) they locally exceed 275 feet. Even in the central valley the combined thickness of till and outwash is generally greater than 200 feet. Lenticular deposits of sand and gravel are common within the till. Furthermore, outwash occurs extensively along the river flood plain, although most commonly it is covered by a few feet of till or alluvium.

Well supplies in the basin are obtained from coarse-grained deposits that commonly exceed 40 feet in thickness. Municipal wells, such as those at Edon, Montpelier and Edgerton, yield between 200 and 465 gpm. It has been predicted (Walker, 1959) that well yields may exceed 500 gpm throughout the basin in Ohio. The estimate is, of course, preliminary and only general in nature.

The region has low to moderate relief and the major slopes are toward the St. Joseph River.

Annual precipitation in the basin during water years 1963, 1967 and 1973 was about 24, 32 and 34 inches, respectively.

The highest stream flows usually occur during the spring runoff in March and periods of low flow may extend from September through February. During a year of normal precipitation (1967) the flow-duration curve began to approach the horizontal at about the 75 percent flow; the 90 percent flow was 0.041 cfs/sq.mi.

Effective ground-water recharge rates in the St. Joseph River basin are shown in Table 5-2. Based on the Local Minima (7 day) separation technique, the rates ranged from a low of 101,000 gpd/sq. mi. or 2.89 inches (64.48 percent of runoff) during 1963, to 236,000 gpd/sq. mi. during a year of normal precipitation (1967), to a maximum of 505,000 during the wet year of 1973. These rates are equal to about 12, 15 and 18 percent of each years precipitation.

During 1963, 1967, and 1973, monthly recharge rates ranged from lows of 39,000 (January), 21,000 (September), and 57,000 (September) gpd/sq. mi. to highs of 378,000, 896,000, and 1,381,000 in March, respectively (Table 5-3). Flow ratios are moderately high as would be expected for a basin that contains a considerable amount of sand and gravel. Base flow occurs at about the 70 percent flow duration.

The concentration of dissolved solids, hardness and chloride in well water in the St. Joseph Basin average 384,320 and 13 mg/l, respectively. During base-flow conditions, surface-water samples contained averages of 357,358 and 12 mg/l and therefore the concentrations differ from well water by only 10 percent or less. The background concentration of sulfate in ground water should average about 51 mg/l.

Throughout nearly the entire drainage basin of the St. Mary's River, bedrock consists predominantly of carbonate rocks of Silurian age that become progressively younger northward. The upward migration of water from the limestone aquifers is probably small because of the thick deposits of glacial till that overlie the bedrock surface.

Except for some buried outwash in the Fort Wayne Moraine and a small amount of surficial outwash along the lower reaches of the Saint Mary's, thick deposits of glacial till mantle the entire region. For the most part, these deposits range between 50 and 100 feet in thickness. A major pre-glacial river channel, however, cuts across the southwest part of Auglaize County into Lake St. Mary's and then trends northwestward across the upper half of Mercer County, before entering Indiana. Glacial deposits, largely till, fill this valley to such an extent that it has no surface expression.

Most of the wells in the basin obtain water from solution openings in the carbonate rock aquifer and yields of 300 gpm or more have been obtained from depths of around 300 feet. Extensive ground-water supplies are also available in the buried valleys, along their margins, and locally from thick deposits of sand and gravel. Those wells that tap neither the limestone aquifer or buried valley aquifers obtain water from isolated aquifers within the drift.

The basin has very low relief except along end moraines, which may rise a few tens of feet above the surrounding plain.

Effective ground water recharge rate in the Saint Mary's River Basin are shown in Table 5-2.

On the basis of the local minima method the rates range from a low of 91,000 (1.92 inches) gpd/mi. sq. during 1963, to 189,000 (4.97 inches) in 1967, to a maximum of 364,000 (10.61 inches) during 1973.

Water from wells that tap buried deposits of sand and gravel in the glacial till and from streams during low flow generally contain 450 to 500 mg/l of dissolved solids. Hardness averages around 400 mg/l, chloride concentrations average about 40 mg/l and sulfate ranges from 50 to about 150. These concentrations contrast considerably with water in the limestone aquifer where dissolved solids commonly exceed 1000 mg/l, hardness exceeds 700 mg/l, chloride is generally less than 10 mg/l and sulfate commonly exceeds 200 mg/l.

Tiffin River and its major tributaries, Bean and Lime Creeks, originate in the hilly and high morainal deposits in Hillsdale and Lenawee Counties, Michigan. The mainstem flows southward to join the Maumee River at Defiance. The drainage area contains 804 square miles of which 251 lie in Michigan. With the exception of Brush Creek and a few small tributaries, all of the major streams that feed the Tiffin originate on the eastern flank of the Fort Wayne Moraine. These include Mill, Lick, and Lost Creeks, among others.

Throughout the Tiffin basin, bedrock is composed predominantly of shale of Mississippian and Devonian age, which is covered by till. The till, which exceeds 200 feet in thickness in the north, gradually thins southward and is about 50 feet thick at Defiance. In part of the low area between the Fort

Wayne and Defiance Moraines are glacial lake deposits that consist of silt and clay and throughout much of its length the Tiffin River flows over these fine-grained materials. Lying west of a line between Archbold and Ney is an abundance of sand and gravel buried within the till. Wells, generally ranging from 30 to 150 feet in depth, obtain their supplies from these coarse deposits. Locally, as at Bryan, individual well yields may exceed 1500 gpm. Because of designed characteristics most wells yield less than 20 gpm. Skirting northeast-southwest through the central part of the basin is a belt, 5 to 7 miles wide, in which wells commonly flow. They derive their head from recharge along the higher parts of the Fort Wayne Moraine to the west. Bean Creek nearly bisects this belt and the upward component of ground-water flow probably accounts for its high sustained flow. Along the southeastern quarter of the basin, sand and gravel are much less abundant and many wells are drilled to the fractured and weather upper part of the underlying shale; yields rarely exceed 5 gpm.

Relief in the basin ranges from the low, nearly featureless terrain in the lower parts to the high hummocky headwaters in Michigan.

Effective ground-water recharge rates in the Tiffin River basin are shown in Table 5-2. In the Bean Creek area the rates ranged from a low of 116,000 (2.46 inches) gpd/sq. mi. during 1963, to 327,000 (6.87 inches) during 1967 to a maximum of 503,000 (10.57 inches) in 1973. Farther downstream on the Tiffin River, effective recharge rates during the cited periods ranged from 62,000 (1.32 inches), 274,000 (5.77 inches), and 421,000 (8.85 inches) gpd/sq. mi. In Bean Creek monthly recharge rates range from a low of 93,000 gpd/sq. mi. in June 1963 to a high of 1,553,000 in March 1973 (Table 5-3).

Although very hard (352 to 410 mg/1), ground-water quality in the Tiffin basin is only moderately mineralized. Concentrations of chloride, dissolved solids and sulfate average about 15,400, and 80 mg/l, respectively. Not uncommonly, however, the concentration of chloride far exceeds the average concentration, reaching a maximum that exceeds 300 mg/l.

The Auglaize River originates on the distal side of the Wabash Moraine in Auglaize County. Much of its flow is derived from a mass of outwash that lies adjacent to the moraine in the vicinity of Wapakoneta. The river breaches the moraine at Wapakoneta and flows northward to join the Maumee River at Defiance. It drains an area of 2448.2 square miles as it flows nearly 102 miles across the low relief till plain.

Throughout the Auglaize River basin, bedrock consists of limestone that is covered by 25 to 50 feet of till and lake sediments. A buried valley, containing as much as 300 feet of till and outwash, extends southeastward from Lima through Wapakoneta and joins another channel that continues through Grand Lake St. Marys. Another channel nearly bisects Putnam County and trends directly under the city of Ottawa.

Throughout much of the basin ground-water supplies are obtained from wells that tap the limestone aquifer. Supplies are also obtained from outwash and buried valleys and lenticular deposits of sand and gravel buried within the till. Locally wells that tap buried valley aquifers produce 200 gpm or more, while wells in the carbonate aquifer may yield more than 400 gpm.

Over most of the basin the relief is very low, although in the vicinity of end moraines, such as the Wabash, Fort Wayne, and Defiance, the relief is moderate.

Effective ground-water recharge rates in the Auglaize River Basin are shown in Table 5-2. During a year of normal precipitation they range between 100,000 and 200,000 gpd/sq. mi. An exception occurs along the Ottawa River in the vicinity of Lima where the rates range between 200,000 and 300,000 gpd/sq. mi.

This is probably due to ground-water discharge from both the buried valley that lies in this region and buried outwash. Maximum and minimum monthly recharge rates are shown in Table 5-3. Flow ratios are low as would be expected for a basin of low relief that contains practically no outwash (Table 5-4).

## Sandusky and Portage River Basins

The Portage River originates along the northern flank of the Defiance Moraine (Fig. 5-5). It makes a broad northeastward trending loop, nearly 61 miles long, before entering Lake Erie at Port Clinton. The basin contains 587 square miles. Major tributaries to the Portage include Middle Branch, Rocky Ford, Bow Creek, South and East Branch, Sugar Creek, and Nine Mile Creek, among others. All are low gradient sluggish streams and most flow either northward or eastward before entering the Portage.

Bedrock in the Portage Basin consists of carbonates and these are overlain by glacial deposits. Most of the glacial material is low relief ground moraine that is overlapped along the margin of Lake Erie, particularly in large parts of Ottawa and Sandusky Counties, by fine-grained glacial lake deposits. The glacial cover thickens northward; along the southern boundary of the basin it is commonly less than 10 but it approaches 100 feet in thickness along the margin of Lake Erie.

Most ground-water supplies in the Portage Basin are obtained from the carbonate aquifer, which usually yields 75 to 300 gpm. Scattered throughout the glacial till are local deposits of sand and gravel that provide sufficient water to wells for domestic purposes. Within buried valleys, which are numerous but not well defined, outwash locally provides yields in excess of 20 gpm.

The basin slopes gently toward Lake Erie and the relief is very low. The highest stream flows usually occur during the spring runoff and periods

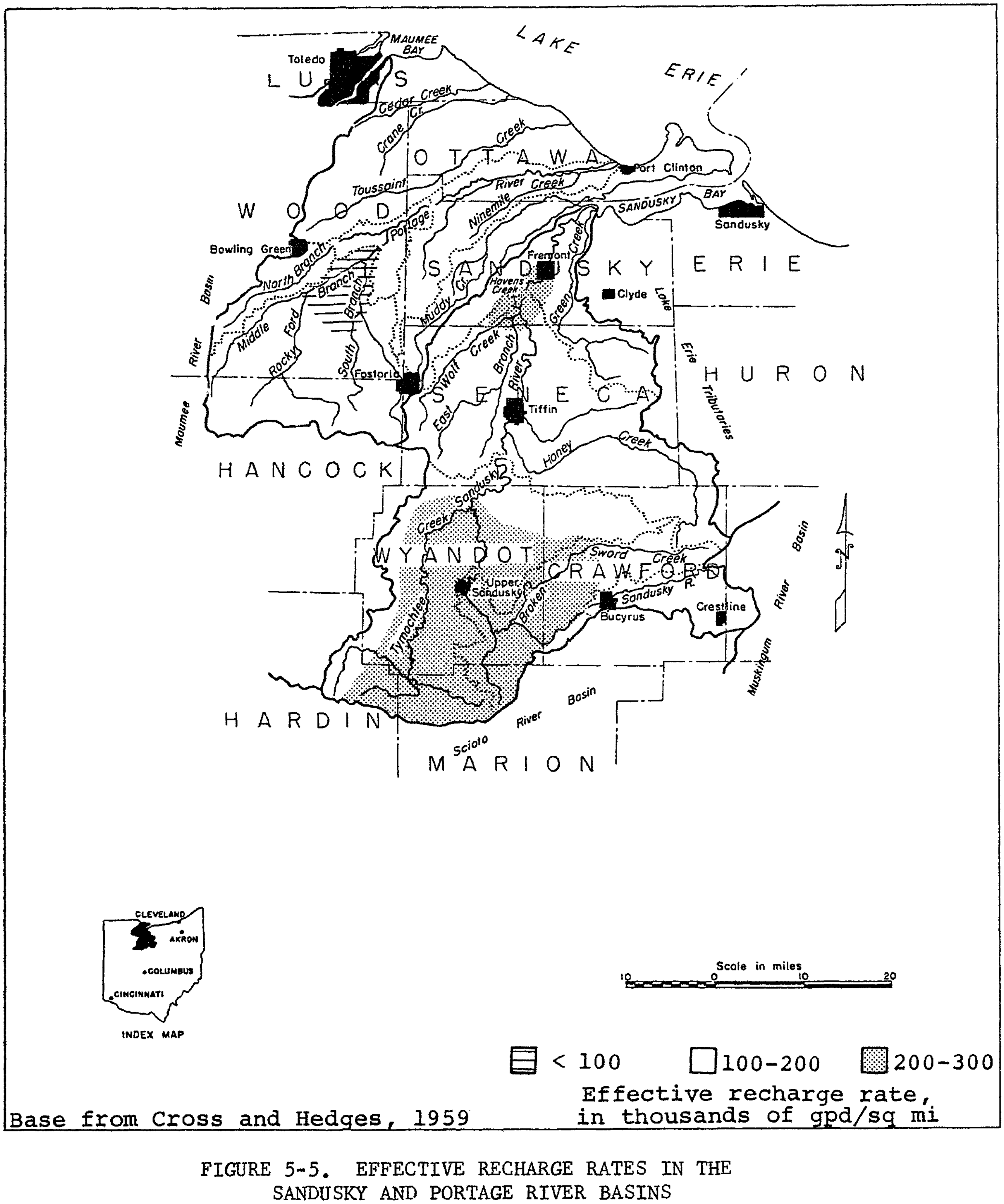



FIGURE 5-5. EFFECTIVE RECHARGE RATES IN THE SANDUSKY AND PORTAGE RIVER BASINS

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4195500 PORTAGE RIVER AT WOODVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 93000. | 100000. | 87000. | 44. | 47. | 41. | 1.97 | 2.11 | 1.83 | 4.46 | 3.36 | 1 | 10 | 4 |
| 67 | 185000. | 199000. | 129000. | 27. | 29. | 19. | 3.90 | 4.19 | 2.72 | 14.54 | 3.36 | 1 | 10 | 4 |
| 73 | 354000. | 354000. | 353000. | 37. | 37. | 37. | 7.46 | 7.44 | 7.42 | 19.91 | 3.36 | 1 | 10 | 4 |
| 4196000 SANDUSKY RIVER NEAR BUCYRUS, OHIO | | | | | | | | | | | | | | |
| 67 | 276000. | 298000. | 299000. | 39. | 42. | 42. | 5.81 | 6.26 | 6.29 | 15.02 | 2.45 | 1 | 21 | 3 |
| 73 | 411000. | 404000. | 349000. | 39. | 38. | 33. | 8.64 | 8.50 | 7.34 | 22.09 | 2.45 | 1 | 21 | 3 |
| 4196500 SANDUSKY RIVER NEAR UPPER SANDUSKY, OHIO | | | | | | | | | | | | | | |
| 63 | 126000. | 140000. | 130000. | 33. | 37. | 34. | 2.66 | 2.95 | 2.73 | 7.96 | 3.12 | 1 | 10 | 4 |
| 67 | 240000. | 244000. | 226000. | 37. | 38. | 35. | 5.06 | 5.15 | 4.76 | 13.66 | 3.12 | 1 | 10 | 4 |
| 73 | 393000. | 386000. | 390000. | 40. | 40. | 40. | 8.26 | 8.12 | 8.21 | 20.47 | 3.12 | 1 | 10 | 4 |
| 4196800 TYMOCHTEE CREEK AT CRAWFORD, OHIO | | | | | | | | | | | | | | |
| 67 | 251000. | 271000. | 208000. | 39. | 42. | 32. | 5.28 | 5.69 | 4.37 | 13.57 | 2.96 | 1 | 10 | 4 |
| 73 | 392000. | 415000. | 347000. | 42. | 45. | 37. | 8.24 | 8.72 | 7.30 | 19.48 | 2.96 | 1 | 10 | 4 |
| 4197000 SANDUSKY RIVER NEAR MEXICO,OHIO | | | | | | | | | | | | | | |
| 63 | 131000. | 157000. | 136000. | 36. | 43. | 37. | 2.76 | 3.31 | 2.86 | 7.66 | 3.78 | 1 | 21 | 4 |
| 67 | 223000. | 251000. | 196000. | 34. | 38. | 30. | 4.68 | 5.27 | 4.12 | 13.96 | 3.78 | 1 | 21 | 4 |
| 73 | 410000. | 405000. | 365000. | 43. | 42. | 38. | 8.62 | 8.51 | 7.67 | 20.05 | 3.78 | 1 | 21 | 4 |

TABLE 5-5. RECHARGE STATISTICS FOR THE PORTAGE-SANDUSKY RIVER BASINS

TABLE 5-5 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4198000 SANDUSKY RIVER NEAR FREMONT, OHIO | | | | | | | | | | | | | | |
| 63 | 135000. | 146000. | 119000. | 37. | 40. | 33. | 2.85 | 3.08 | 3.08 | 7.72 | 4.16 | 1 | 30 | 4 |
| 67 | 195000. | 221000. | 185000. | 28. | 32. | 27. | 4.11 | 4.65 | 4.65 | 14.55 | 4.16 | 1 | 30 | 4 |
| 73 | 417000. | 388000. | 361000. | 42. | 39. | 37. | 8.77 | 8.17 | 8.54 | 20.70 | 4.16 | 1 | 30 | 4 |

PORTAGE-SANDUSKY BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 4195500 PORTAGE RIVER AT WOODVILLE, OHIO | | | | | | | | | | | | |
| FX | 10000. | 18000. | 12000. | 15000. | 24000. | 763000. | 147000. | 57000. | 30000. | 13000. | 15000. | 5532. |
| SL | 10000. | 18000. | 11000. | 16000. | 26000. | 820000. | 155000. | 59000. | 40000. | 15000. | 12000. | 5466. |
| LM | 9773. | 18000. | 11000. | 15000. | 21000. | 694000. | 154000. | 57000. | 24000. | 13000. | 11000. | 5339. |
| 67 | | | | | | | | | | | | |
| FX | 11000. | 110000. | 521000. | 110000. | 248000. | 558000. | 332000. | 208000. | 33000. | 40000. | 32000. | 19000. |
| SL | 12000. | 188000. | 679000. | 95000. | 252000. | 472000. | 325000. | 304000. | 32000. | 36000. | 29000. | 14000. |
| LM | 11000. | 51000. | 139000. | 100000. | 241000. | 435000. | 340000. | 121000. | 34000. | 40000. | 29000. | 12000. |
| 73 | | | | | | | | | | | | |
| FX | 179000. | 678000. | 525000. | 274000. | 200000. | 1215000. | 462000. | 293000. | 240000. | 144000. | 17000. | 11000. |
| SL | 182000. | 733000. | 567000. | 285000. | 212000. | 1088000. | 441000. | 301000. | 261000. | 135000. | 18000. | 11000. |
| LM | 140000. | 765000. | 506000. | 350000. | 215000. | 1125000. | 405000. | 285000. | 258000. | 144000. | 14000. | 11000. |
| 63 4196500 SANDUSKY RIVER NEAR UPPER SANDUSKY, OHIO | | | | | | | | | | | | |
| FX | 18000. | 52000. | 64000 | 72000. | 61000. | 828000. | 257000. | 77000. | 51000. | 11000. | 11000. | 2906. |
| SL | 19000. | 51000. | 64000. | 76000. | 58000. | 988000. | 246000. | 77000. | 58000. | 14000. | 10000. | 2631. |
| LM | 22000. | 50000. | 66000. | 64000. | 48000. | 899000. | 237000. | 82000. | 47000. | 17000. | 9240. | 2344. |
| 67 | | | | | | | | | | | | |
| FX | 30000. | 172000. | 407000. | 156000. | 298000. | 798000. | 392000. | 456000. | 74000. | 47000. | 33000. | 18000. |
| SL | 29000. | 220000. | 498000. | 132000. | 296000. | 703000. | 356000. | 531000. | 67000. | 49000. | 33000. | 16000. |
| LM | 26000. | 86000. | 236000. | 156000. | 286000. | 682000. | 346000. | 726000. | 69000. | 47000. | 32000. | 15000. |
| 73 | | | | | | | | | | | | |
| FX | 207000. | 652000. | 641000. | 376000. | 282000. | 909000. | 504000. | 394000. | 335000. | 287000. | 80000. | 31000. |
| SL | 214000. | 681000. | 665000. | 310000. | 294000. | 846000. | 482000. | 403000. | 351000. | 261000. | 87000. | 31000. |
| LM | 171000. | 723000. | 652000. | 389000. | 311000. | 881000. | 497000. | 342000. | 340000. | 270000. | 71000. | 31000. |
| 63 4197000 SANDUSKY RIVER NEAR MEXICO, OHIO | | | | | | | | | | | | |
| FX | 23000. | 70000. | 63000. | 72000. | 50000. | 895000. | 234000. | 60000. | 47000. | 18000. | 18000. | 9188. |
| SL | 25000. | 67000. | 63000. | 73000. | 57000. | 1198000. | 221000. | 59000. | 56000. | 19000. | 18000. | 9224. |
| LM | 23000. | 72000. | 64000. | 63000. | 43000. | 997000. | 208000. | 64000. | 35000. | 18000. | 19000. | 9816. |
| 67 | | | | | | | | | | | | |
| FX | 30000. | 154000. | 390000. | 140000. | 287000. | 674000. | 377000. | 408000. | 86000. | 64000. | 36000. | 22000. |
| SL | 30000. | 209000. | 530000. | 110000. | 296000. | 681000. | 351000. | 586000. | 90000. | 65000. | 33000. | 20000. |
| LM | 26000. | 87000. | 220000. | 133000. | 283000. | 680000. | 343000. | 363000. | 86000. | 68000. | 42000. | 19000. |
| 73 | | | | | | | | | | | | |
| FX | 219000. | 682000. | 658000. | 418000. | 277000. | 1105000. | 486000. | 395000. | 332000. | 199000. | 92000. | 43000. |
| SL | 227000. | 782000. | 672000. | 336000. | 294000. | 1038000. | 483000. | 378000. | 320000. | 229000. | 95000. | 42000. |
| LM | 182000. | 789000. | 655000. | 455000. | 308000. | 577000. | 486000. | 327000. | 315000. | 191000. | 62000. | 41000. |

TABLE 5-6. MONTHLY RECHARGE RATES FOR THE PORTAGE-SANDUSKY RIVER BASINS

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 4195500 PORTAGE RIVER AT WOODVILLE, OHIO | | | | | | | | | |
| 63 | 7.85461 | 2.28416 | 0.01098 | 0.01379 | 0.02150 | 0.02570 | 0.03505 | 0 | 0 |
| 67 | 10.63112 | 4.13506 | 0.01893 | 0.02243 | 0.04731 | 0.12150 | 0.22664 | 0 | 0 |
| 73 | 10.86278 | 2.85782 | 0.01963 | 0.02921 | 0.20619 | 0.44159 | 0.69042 | 0 | 0 |
| 4196000 SANDUSKY RIVER NEAR BUCYRUS, OHIO | | | | | | | | | |
| 67 | 7.79087 | 3.46828 | 0.04054 | 0.04842 | 0.07770 | 0.19144 | 0.29842 | 0 | 0 |
| 73 | 6.11555 | 2.15783 | 0.08446 | 0.11261 | 0.36036 | 0.58559 | 0.78266 | 0 | 0 |
| 4196500 SANDUSKY RIVER NEAR UPPER SANDUSKY, OHIO | | | | | | | | | |
| 63 | 9.01586 | 2.51812 | 0.00638 | 0.01174 | 0.03691 | 0.07047 | 0.09396 | 0 | 0 |
| 67 | 7.42823 | 3.68394 | 0.03356 | 0.04698 | 0.07047 | 0.16107 | 0.27852 | 0 | 0 |
| 73 | 5.85946 | 2.25055 | 0.06376 | 0.10067 | 0.33557 | 0.58389 | 0.82383 | 0 | 0 |
| 4196800 TYMOCHTEE CREEK AT CRAWFORD, OHIO | | | | | | | | | |
| 67 | 26.45750 | 5.36554 | 0.00148 | 0.00437 | 0.02795 | 0.07860 | 0.18122 | 0 | 0 |
| 73 | 6.68580 | 3.16583 | 0.04279 | 0.08734 | 0.19432 | 0.38428 | 0.69214 | 0 | 0 |
| 4197000 SANDUSKY RIVER NEAR MEXICO,OHIO | | | | | | | | | |
| 63 | 7.12741 | 2.22812 | 0.01550 | 0.01938 | 0.04554 | 0.07364 | 0.08915 | 0 | 0 |
| 67 | 8.21584 | 3.37978 | 0.03876 | 0.04393 | 0.08172 | 0.16796 | 0.27455 | 0 | 0 |
| 73 | 5.58721 | 2.47825 | 0.07752 | 0.12209 | 0.32817 | 0.59302 | 0.79845 | 0 | 0 |

TABLE 5-7. FLOW-RATIO STATISTICS FOR THE PORTAGE-SANDUSKY RIVER BASINS

TABLE 5-7 CONTINUED

4198000 SANDUSKY RIVER NEAR FREMONT, OHIO

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 6.87806 | 2.44069 | 0.01199 | 0.02078 | 0.03717 | 0.06395 | 0.08473 | 0 | 0 |
| 67 | 8.53564 | 3.78770 | 0.03677 | 0.03917 | 0.07494 | 0.18385 | 0.31295 | 0 | 0 |
| 73 | 6.71865 | 2.56281 | 0.05436 | 0.08553 | 0.31735 | 0.59952 | 0.85132 | 0 | 0 |

of low flow extend from late summer through early winter.

Effective ground-water recharge rates in the Portage River Basin are shown in Table 5-5. The rates range from a low of 87,000 during 1963, to 129,000 during 1967, to a maximum of 353,000 gpd/mi. sq. during 1973.

Monthly recharge rates range from a low of 5500 gpd/sq. mi. in September 1963 to a high of 1,125,000, the latter of which occurred in March 1973 (Table 5-6). Flow ratios are moderately low (Table 5-7). Base flow occurs at about the 90 percent flow duration.

The Sandusky River originates in Crawford County and flows along the distal margin of the Wabash Moraine, which it breaches in the southeast corner of Wyandot County (Fig. 5-5). It continues northwestward and eventually swings to the northeast as it breaches the Fort Wayne and Defiance Moraines before discharging into Sandusky Bay north of Fremont. Much of the base flow of the Sandusky River originates in Crawford County where the stream valley is underlain by outwash. Baseflow is also obtained from outwash deposits along Broken Sword Creek, which lies just to the north. Major tributaries to the Sandusky River include Tymochtee, and Wolfe Creeks, which enter from the west, and Broken Sword, Sycamore, Honey, and Green Creeks, which enter from the east.

Most of the Sandusky River basin is underlain by carbonate bedrock. An exception occurs, however, in the southeastern corner where, east of the line between Bucyrus and northeast corner of Seneca County, shale and thin layers of sandstone subcrop beneath the till. These bedrock deposits consist of the Olentangy and Ohio Shales of Devonian age. Glacial material, which covers the entire drainage basin, ranges in thickness from 10 to about 140 feet, and generally thickens northward.

Most of the ground-water supplies in the Sandusky River basin are obtained from the limestone aquifer. Yields range widely but 200 to 300 gpm are usually available from depths of around 300 feet. The glacial deposits are only minor sources of ground-water, but isolated pockets of sand and gravel may provide as much as 10 gpm to wells.

The region has a low to moderate relief; the greatest changes in topography occur in the vicinity of the end moraines. The highest streamflows usually occur in March, while periods of low flow may extend from September through February.

Effective ground-water recharge rates in the Sandusky River Basin are shown in Table 5-5. They ranged from a low of about 119,000 gpd/sq. mi. during 1963 to a maximum of 390,000 during the wet year of 1973.

During 1963, 1967, and 1973, monthly recharge rates ranged from a low of 9800, 19,000 and 41,000 to highs of 997,000, 680,000 and 881,000 gpd/sq. mi. in March, respectively. Flow ratios are moderately low as would be expected for a basin that contains only a limited amount of outwash (Table 5-7).

## Huron to Rocky River

Four major streams drain to Lake Erie along the stretch from Sandusky to Cleveland. Huron, Vermilion, and Black Rivers are all about 60 miles long, have an average gradient of about 8 feet per mile, with drainage basins of 403, 272 and 467 square miles, respectively. Rocky River has an average fall of 14 feet per mile, is about 50 miles long, and drains 294 square miles. The drainage basins are all relatively flat, glaciated till plains. A narrow strip of Lake Plains province trends along the shore of Lake Erie and eastward the Glaciated Plateau is easily distinguished where Rocky River has cut a steepwalled gorge into shales and sandstones before reaching the narrow Lake Plain.

The region is almost entirely covered with glacial materials, which range from a thin veneer to more than 150 feet in thickness. Along the escarpment,

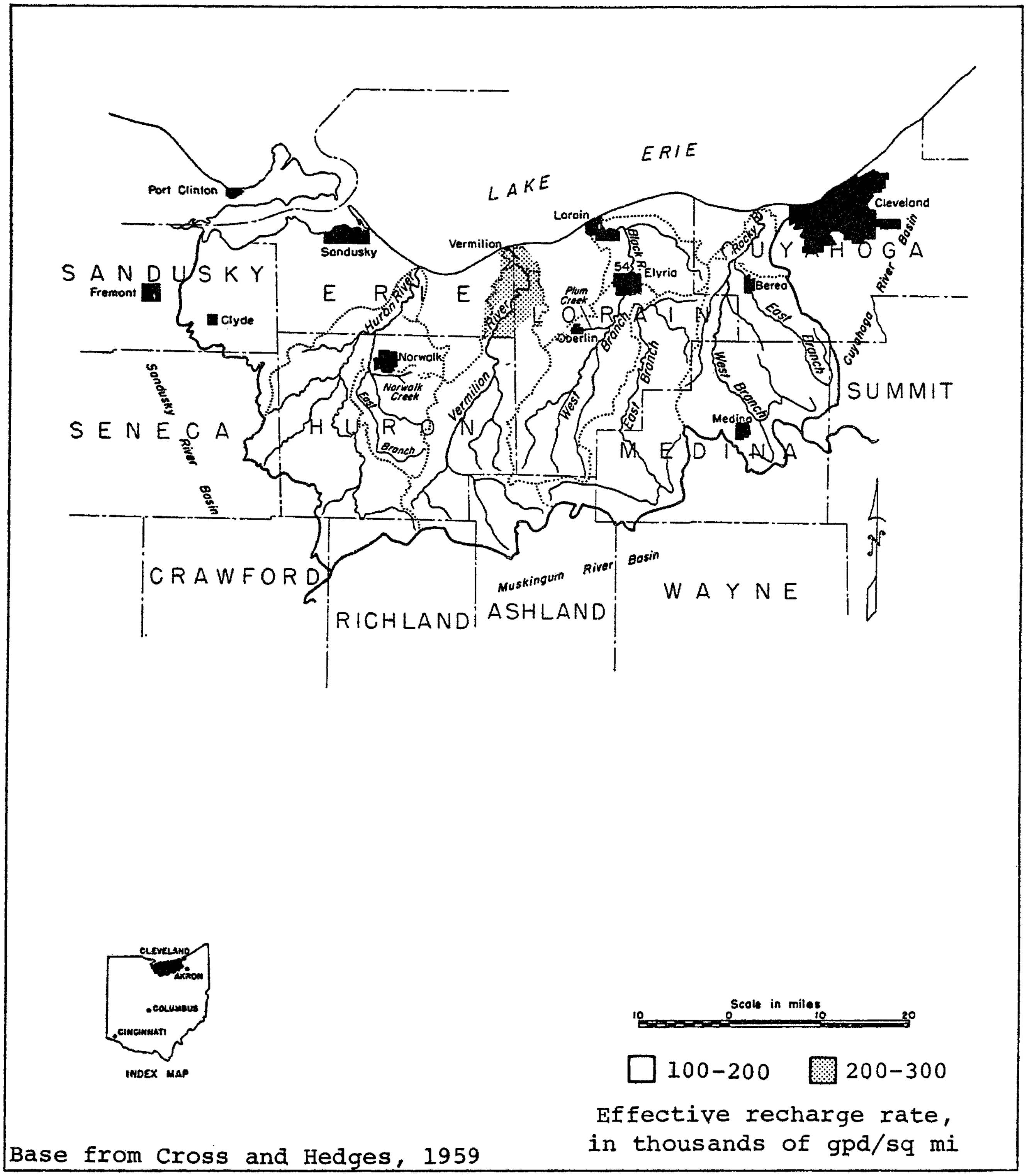



FIGURE 5-6. EFFECTIVE RECHARGE RATES IN THE HURON-ROCKY RIVER BASIN

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4199000 HURON RIVER BELOW MILAN, OHIO | | | | | | | | | | | | | | |
| 63 | 141000. | 159000. | 143000. | 38. | 43. | 39. | 2.98 | 3.35 | 3.01 | 7.81 | 3.26 | 1 | 30 | 3 |
| 67 | 199000. | 205000. | 172000. | 33. | 34. | 29. | 4.19 | 4.31 | 3.61 | 12.61 | 3.26 | 1 | 30 | 3 |
| 73 | 359000. | 362000. | 340000. | 39. | 39. | 37. | 7.56 | 7.61 | 7.15 | 19.30 | 3.26 | 1 | 30 | 3 |
| 4199500 VERMILION RIVER NEAR VERMILION, OHIO | | | | | | | | | | | | | | |
| 63 | 167000. | 199000. | 165000. | 36. | 43. | 35. | 3.52 | 4.20 | 3.47 | 9.80 | 3.05 | 1 | 30 | 3 |
| 67 | 188000. | 198000. | 202000. | 29. | 31. | 31. | 3.96 | 4.16 | 4.66 | 13.59 | 3.05 | 1 | 30 | 3 |
| 73 | 375000. | 375000. | 345000. | 38. | 38. | 35. | 7.88 | 7.89 | 7.26 | 20.67 | 3.05 | 1 | 30 | 3 |
| 4200500 BLACK RIVER AT ELYRIA, OHIO | | | | | | | | | | | | | | |
| 63 | 130000. | 157000. | 132000. | 35. | 43. | 36. | 2.75 | 3.31 | 2.78 | 7.74 | 3.31 | 1 | 30 | 3 |
| 67 | 144000. | 152000. | 160000. | 29. | 31. | 33. | 3.03 | 3.21 | 3.38 | 10.37 | 3.31 | 1 | 30 | 3 |
| 73 | 325000. | 326000. | 304000. | 37. | 37. | 35. | 6.84 | 6.86 | 6.39 | 18.31 | 3.31 | 1 | 30 | 3 |
| 4201500 ROCKY RIVER NEAR BEREA, OHIO | | | | | | | | | | | | | | |
| 63 | 169000. | 196000. | 206000. | 35. | 40. | 42. | 3.56 | 4.12 | 4.33 | 10.20 | 3.06 | 1 | 30 | 3 |
| 67 | 177000. | 184000. | 156000. | 32. | 33. | 28. | 3.73 | 3.88 | 3.29 | 11.83 | 3.06 | 1 | 30 | 3 |
| 73 | 409000. | 420000. | 422000. | 41. | 42. | 42. | 8.61 | 8.83 | 8.87 | 21.09 | 3.06 | 1 | 30 | 3 |

TABLE 5-8. RECHARGE STATISTICS FOR THE HURON TO ROCKY RIVER BASINS

HURON BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 4199000 HURON RIVER BELOW MILAN, OHIO | | | | | | | | | | | | |
| FX | 39000. | 112000. | 110000. | 103000. | 83000. | 846000. | 250000. | 81000. | 29000. | 13000. | 14000. | 8594. |
| SL | 40000. | 110000. | 111000. | 105000. | 97000. | 1033000. | 252000. | 79000. | 29000. | 12000. | 15000. | 8745. |
| LM | 40000. | 125000. | 98000. | 90000. | 80000. | 883000. | 241000. | 82000. | 29000. | 12000. | 14000. | 8913. |
| 67 | | | | | | | | | | | | |
| FX | 17000. | 135000. | 302000. | 115000. | 276000. | 612000. | 398000. | 349000. | 83000. | 48000. | 29000. | 26000. |
| SL | 16000. | 142000. | 373000. | 103000. | 285000. | 543000. | 379000. | 445000. | 74000. | 48000. | 29000. | 20000. |
| LM | 16000. | 115000. | 196000. | 118000. | 247000. | 514000. | 384000. | 305000. | 72000. | 46000. | 30000. | 19000. |
| 73 | | | | | | | | | | | | |
| FX | 204000. | 568000. | 617000. | 299000. | 251000. | 969000. | 419000. | 388000. | 327000. | 147000. | 70000. | 41000. |
| SL | 205000. | 621000. | 631000. | 234000. | 257000. | 973000. | 428000. | 358000. | 325000. | 140000. | 68000. | 40000. |
| LM | 173000. | 610000. | 594000. | 279000. | 259000. | 806000. | 439000. | 325000. | 337000. | 139000. | 73000. | 41000. |
| 63 4200500 BLACK RIVER AT ELYRIA, OHIO | | | | | | | | | | | | |
| FX | 39000. | 99000. | 117000. | 77000. | 67000. | 824000. | 204000. | 64000. | 24000. | 15000. | 13000. | 7888. |
| SL | 40000. | 98000. | 123000. | 83000. | 76000. | 1118000. | 208000. | 62000. | 25000. | 15000. | 14000. | 7834. |
| LM | 42000. | 98000. | 106000. | 67000. | 65000. | 869000. | 194000. | 66000. | 25000. | 16000. | 14000. | 8075. |
| 67 | | | | | | | | | | | | |
| FX | 13000. | 70000. | 185000. | 74000. | 144000. | 633000. | 306000. | 221000. | 37000. | 16000. | 10000. | 8813. |
| SL | 14000. | 75000. | 241000. | 69000. | 150000. | 563000. | 287000. | 355000. | 35000. | 15000. | 10000. | 8813. |
| LM | 14000. | 69000. | 97000. | 78000. | 131000. | 552000. | 288000. | 619000. | 36000. | 15000. | 10000. | 7305. |
| 73 | | | | | | | | | | | | |
| FX | 202000. | 571000. | 531000. | 250000. | 303000. | 1001000. | 320000. | 314000. | 257000. | 95000. | 30000. | 18000. |
| SL | 200000. | 603000. | 585000. | 245000. | 300000. | 971000. | 318000. | 313000. | 237000. | 89000. | 29000. | 16000. |
| LM | 165000. | 618000. | 550000. | 271000. | 246000. | 805000. | 350000. | 241000. | 234000. | 106000. | 36000. | 16000. |
| 67 4201500 ROCKY RIVER NEAR BEREA, OHIO | | | | | | | | | | | | |
| FX | 28000. | 96000. | 226000. | 132000. | 238000. | 654000. | 366000. | 284000. | 41000. | 27000. | 16000. | 18000. |
| SL | 27000. | 110000. | 301000. | 133000. | 245000. | 593000. | 345000. | 358000. | 39000. | 27000. | 15000. | 16000. |
| LM | 28000. | 93000. | 164000. | 131000. | 218000. | 586000. | 347000. | 211000. | 39000. | 27000. | 15000. | 14000. |
| 73 | | | | | | | | | | | | |
| FX | 248000. | 739000. | 733000. | 278000. | 391000. | 1053000. | 528000. | 436000. | 265000. | 112000. | 73000. | 53000. |
| SL | 222000. | 779000. | 800000. | 270000. | 382000. | 1097000. | 556000. | 485000. | 236000. | 100000. | 66000. | 41000. |
| LM | 191000. | 797000. | 795000. | 304000. | 344000. | 1039000. | 584000. | 537000. | 247000. | 109000. | 65000. | 41000. |

TABLE 5-9. MONTHLY RECHARGE RATES FOR THE HURON TO ROCKY RIVER BASINS

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 4199000 HURON RIVER BELOW MILAN, OHIO | | | | | | | | | |
| 63 | 7.38424 | 2.77836 | 0.01590 | 0.01995 | 0.03841 | 0.09164 | 0.13342 | 0 | 0 |
| 67 | 7.90795 | 3.15238 | 0.02965 | 0.03774 | 0.08625 | 0.16173 | 0.26954 | 0 | 0 |
| 73 | 5.84034 | 2.31497 | 0.07547 | 0.09838 | 0.29650 | 0.49326 | 0.67116 | 0 | 0 |
| 4199500 VERMILION RIVER NEAR VERMILION, OHIO | | | | | | | | | |
| 63 | 21.90889 | 4.21637 | 0.00038 | 0.00324 | 0.01718 | 0.07634 | 0.12023 | 0 | 15 |
| 67 | 14.68181 | 4.57712 | 0.00763 | 0.01202 | 0.03817 | 0.09924 | 0.17557 | 0 | 0 |
| 73 | 9.02986 | 2.26465 | 0.03015 | 0.04962 | 0.32634 | 0.51145 | 0.76908 | 0 | 0 |
| 4200500 BLACK RIVER AT ELYRIA, OHIO | | | | | | | | | |
| 63 | 7.28011 | 2.50881 | 0.01515 | 0.02020 | 0.04293 | 0.07576 | 0.10480 | 0 | 0 |
| 67 | 9.69858 | 4.08831 | 0.01515 | 0.02020 | 0.03535 | 0.07828 | 0.12500 | 0 | 0 |
| 73 | 8.58778 | 2.39223 | 0.03030 | 0.05051 | 0.25505 | 0.45455 | 0.60859 | 0 | 0 |
| 4201500 ROCKY RIVER NEAR BEREA, OHIO | | | | | | | | | |
| 63 | 7.98995 | 2.79443 | 0.01536 | 0.02097 | 0.06367 | 0.16105 | 0.18914 | 0 | 0 |
| 67 | 8.17342 | 3.58236 | 0.02622 | 0.03165 | 0.05618 | 0.11610 | 0.21723 | 0 | 0 |
| 73 | 5.50325 | 2.37260 | 0.08989 | 0.13109 | 0.33333 | 0.59176 | 0.76779 | 0 | 0 |

TABLE 5-10. FLOW-RATIO STATISTICS FOR THE HURON TO ROCKY RIVER BASINS

Devonian sandstone and shale lie close to the surface, while Mississippian age rocks underlie the till plains to the south. West of the Huron River, limestone and dolomite locally crop out.

Yields in the limestone can be very high, amounting to several hundreds of gallons a minute. Glacial deposits tend to be poor sources of water, except for scattered sand lenses in the till that can produce as much as 100 gpm. Sandstone and shale units in the area have slight water bearing capacities. Most wells in the sandstones yield less than 25 gpm. Wells in buried valleys generally are not too productive because of the fine materials that fill the valleys.

Annual precipitation in this region during 1963, 1967, and 1973 ranged between 20 to 30, 25 to 35 and 35 to 45 inches, respectively.

The highest streamflow is generally during the spring and after intense rainstorms. From late summer to winter, streamflow is very low and many of the smaller tributatires are dry. In the Huron, Vermillion, Black and Rocky Rivers, respectively, the 90 percent flow during 1967 was 0.038, 0.012, 0.020, and 0.032 cfs/sq mi. (Table 5-10). Flow ratios are very high because of the flashy nature of the streams and the very low flow due to almost no contribution from groundwater during at least the dry season of the year.

Separation of the hydrographs for each stream indicate low effective groundwater recharge rates, except in 1973, which was abnormally wet (Table 5-8 and 5-9). All the separations for the year of normal precipitation were in the range of 100,000 to 200,000 gpd/sq. mi., except for a small area around the Vermilion River. This is probably a result of buried valleys filled with as much as 150 feet of clay and till interbedded with discontinuous lenses of sand and gravel that locally yield greater than 100 gpm.

The chemical quality in this basin is quite variable, especially in the region of intensive water circulation. Oil and gas has been developed in this region and ground-water contamination is not uncommon in localized areas. One area is grossly contaminated from underground disposal of sewage in the area of Bellevue, making the limestone and dolomite unusable as a source of drinking water.

In the sandstone and shale areas, water obtained form the overlying glacial materials shows high hardness (120 to 750 mg/l) and corresponding high dissolved solids (360 to over 1000 mg/l) . It also contains varying amounts of iron and other minor constituents. Most wells have less than 50 mg/l chloride, but those areas contaminated with oil-field brine or sewage have considerably more.

### Cuyahoga River to Conneaut Creek

Five major streams drain to Lake Erie between Cleveland and the Pennsylvania-Ohio border (Fig. 5-7). The Cuyahoga and Grand Rivers are both about 100 miles long with an average gradient of 6 to 7 feet per mile. Chagrin and Ashtabula Rivers, and Conneaut Creek are 40 to 60 miles long with average gradients of 11 to 16 feet per mile. Drainage areas for Cuyahoga, Chagrin, Grand, Ashtabula, and Conneaut are 813, 267, 712, 137, and 191 square miles, respectively. The area drained by these streams is geologically and topographically complex causing wide variations in stream characteristics. The topography varies from the flat Lake Plains which lies in a narrow band along the shore, to the rough, glaciated Allegheny Plateau. A wide variety of glacial deposits including end moraines, periglacial lake silts and clays, and flat till plains further complicate the geology.

Bedrock directly under the drift ranges from Devonian shales to Pennsylvanian conglomerate and sandstone. These rocks do not greatly affect streamflow except where the Sharon Conglomerate crops out along steep valley walls. Most of the ground-water contribution to stream flow is derived from permeable sands

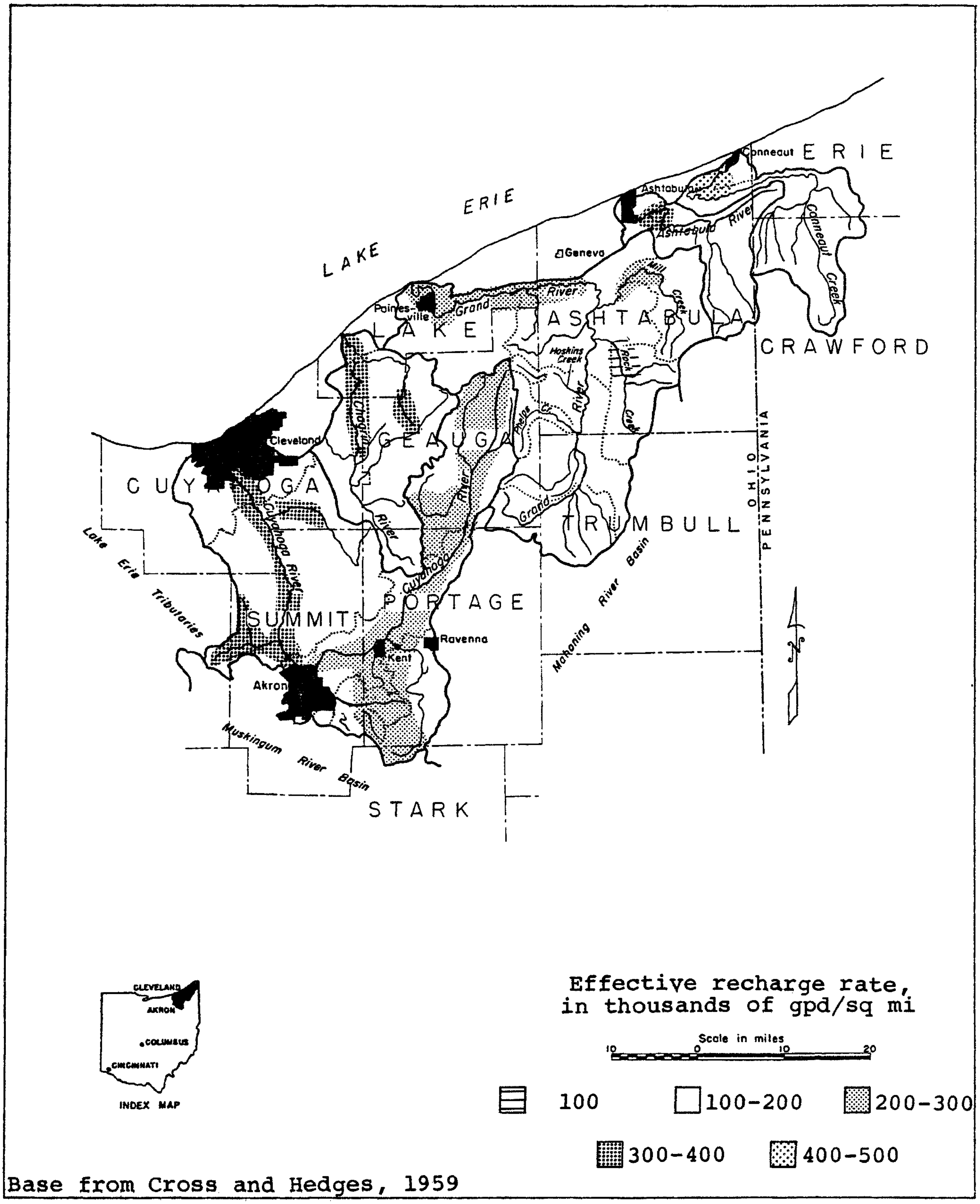



FIGURE 5-7. EFFECTIVE RECHARGE RATES IN CUYAHOGA RIVER TO CONNEAUT CREEK BASINS

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 4202000 CUYAHOGA RIVER AT HIRAM RAPIDS, OHIO | | | | | | | | | |
| 63 | 2.61861 | 1.44288 | 0.21192 | 0.27815 | 0.38411 | 0.48344 | 0.54967 | 0 | 0 |
| 67 | 3.35410 | 2.05206 | 0.17881 | 0.29139 | 0.42384 | 0.56291 | 0.69868 | 0 | 0 |
| 73 | 3.92974 | 2.14504 | 0.17881 | 0.23179 | 0.55629 | 1.01987 | 1.39073 | 0 | 0 |
| 4204000 LITTLE CUYAHOGA RIVER AT MOGADORE, OHIO | | | | | | | | | |
| 63 | 4.11377 | 2.04997 | 0.07692 | 0.09091 | 0.14685 | 0.24476 | 0.32867 | 0 | 0 |
| 67 | 5.72519 | 3.24037 | 0.03497 | 0.06294 | 0.13986 | 0.53846 | 0.76923 | 0 | 0 |
| 73 | 2.19528 | 1.49358 | 0.43353 | 0.47977 | 0.75144 | 1.09827 | 1.27168 | 0 | 0 |
| 4204500 LITTLE CUYAHOGA RIVER AT MASSILON ROAD, AKRON, OH. | | | | | | | | | |
| 63 | 2.81366 | 1.66091 | 0.13608 | 0.15190 | 0.20649 | 0.26582 | 0.30063 | 0 | 0 |
| 67 | 2.90191 | 1.88982 | 0.14873 | 0.18038 | 0.29905 | 0.41139 | 0.53797 | 0 | 0 |
| 73 | 1.97845 | 1.42829 | 0.50633 | 0.55380 | 0.79114 | 1.07595 | 1.26582 | 0 | 0 |
| 4205000 SPRINGFIELD LAKE OUTLET AT AKRON, OHIO | | | | | | | | | |
| 63 | 9.05538 | 3.16228 | 0.01031 | 0.01031 | 0.03093 | 0.04124 | 0.06701 | 0 | 16 |
| 67 | 4.74342 | 2.32832 | 0.01753 | 0.04124 | 0.09794 | 0.16495 | 0.28866 | 0 | 0 |
| 73 | 2.71869 | 1.74801 | 0.20619 | 0.23711 | 0.37113 | 0.63918 | 0.75258 | 0 | 0 |
| 4206000 CUYAHOGA RIVER AT OLD PORTAGE, OHIO | | | | | | | | | |
| 63 | 3.26553 | 1.73405 | 0.12624 | 0.13985 | 0.17822 | 0.22277 | 0.25124 | 0 | 0 |
| 67 | 3.98769 | 2.80059 | 0.13119 | 0.15099 | 0.18564 | 0.28218 | 0.42574 | 0 | 0 |
| 73 | 3.31013 | 1.94239 | 0.20297 | 0.25866 | 0.54765 | 0.99257 | 1.23762 | 0 | 0 |

TABLE 5-11. FLOW-RATIO STATISTICS, CUYAHOGA RIVER TO CONNEAUT CREEK BASINS

TABLE 5-11 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 4207200 TINKERS CREEK AT BEDFORD, OHIO | | | | | | | | | |
| 63 | 5.38500 | 3.91654 | 0.09297 | 0.09774 | 0.16687 | 0.38141 | 0.46484 | 58 | 0 |
| 67 | 5.30512 | 2.67261 | 0.10727 | 0.11561 | 0.16687 | 0.29797 | 0.42908 | 0 | 0 |
| 73 | 4.19183 | 2.29416 | 0.22646 | 0.25030 | 0.45292 | 0.76281 | 1.00119 | 0 | 0 |
| 4208000 CUYAHOGA RIVER AT INDEPENDENCE, OHIO | | | | | | | | | |
| 63 | 3.29773 | 1.64451 | 0.15276 | 0.16973 | 0.22489 | 0.28006 | 0.33239 | 0 | 0 |
| 67 | 3.94771 | 2.51531 | 0.15417 | 0.16337 | 0.21641 | 0.32673 | 0.43352 | 0 | 0 |
| 73 | 2.98511 | 1.93301 | 0.28571 | 0.35714 | 0.59052 | 1.08911 | 1.31683 | 0 | 0 |
| 4208502 BIG CREEK AT CLEVELAND, OHIO | | | | | | | | | |
| 73 | 3.21182 | 1.82117 | 0.15581 | 0.26912 | 0.42493 | 0.59490 | 0.70822 | 0 | 0 |
| 4209000 CHAGRIN RIVER AT WILLOUGHBY, OHIO | | | | | | | | | |
| 63 | 4.39186 | 2.19492 | 0.09756 | 0.10569 | 0.18394 | 0.42683 | 0.49593 | 0 | 0 |
| 67 | 4.50000 | 2.14994 | 0.11382 | 0.13821 | 0.22866 | 0.36179 | 0.44715 | 0 | 0 |
| 73 | 3.87972 | 2.13224 | 0.24390 | 0.27236 | 0.45935 | 0.73171 | 0.97358 | 0 | 0 |
| 4211000 ROCK CREEK NEAR ROCK CREEK, OHIO | | | | | | | | | |
| 63 | 30.53000 | 4.92805 | 0.0 | 0.00100 | 0.01012 | 0.04480 | 0.07876 | 0 | 67 |
| 4211500 MILL CREEK NEAR JEFFERSON, OHIO | | | | | | | | | |
| 63 | 33.16624 | 20.97617 | 0.00122 | 0.00122 | 0.00122 | 0.01220 | 0.10976 | 0 | 0 |
| 67 | 67.47838 | 6.16006 | 0.00061 | 0.00091 | 0.03415 | 0.19512 | 0.31707 | 0 | 0 |
| 73 | 57.87918 | 8.37987 | 0.00122 | 0.00122 | 0.02744 | 0.35366 | 0.60366 | 0 | 0 |

TABLE 5-11 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 4212000 GRAND RIVER NEAR MADISON, OHIO | | | | | | | | | |
| 63 | 14.36141 | 4.33450 | 0.00396 | 0.00688 | 0.02840 | 0.11015 | 0.15491 | 0 | 0 |
| 67 | 11.80727 | 4.79924 | 0.02238 | 0.02926 | 0.06583 | 0.21859 | 0.34079 | 0 | 0 |
| 73 | 11.45931 | 4.03868 | 0.02065 | 0.03270 | 0.14114 | 0.46938 | 0.71256 | 0 | 0 |
| 4212500 ASHTABULA RIVER NEAR ASHTABULA, OHIO | | | | | | | | | |
| 63 | 45.45454 | 9.10377 | 0.0 | 0.00100 | 0.01364 | 0.14876 | 0.31405 | 0 | 45 |
| 67 | 9.44697 | 3.31662 | 0.03636 | 0.04380 | 0.11570 | 0.28926 | 0.39669 | 0 | 0 |
| 73 | 20.78023 | 4.23191 | 0.00669 | 0.00909 | 0.09091 | 0.34711 | 0.61570 | 0 | 0 |
| 4213000 CONNEAUT CREEK AT CONNEAUT, OHIO | | | | | | | | | |
| 63 | 7.09689 | 2.80976 | 0.03943 | 0.04686 | 0.10857 | 0.26286 | 0.37143 | 0 | 0 |
| 67 | 5.46199 | 2.50549 | 0.09714 | 0.13714 | 0.24714 | 0.40000 | 0.52571 | 0 | 0 |
| 73 | 7.82920 | 3.33424 | 0.06857 | 0.07714 | 0.18286 | 0.57143 | 0.93143 | 0 | 0 |

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4202000 CUYAHOGA RIVER AT HIRAM RAPIDS, OHIO | | | | | | | | | | | | | | |
| 63 | 501000. | 518000. | 377000. | 72. | 75. | 54. | 10.53 | 10.88 | 7.92 | 14.57 | 2.73 | 2 | 20 | 2 |
| 67 | 634000. | 619000. | 435000. | 76. | 74. | 52. | 13.32 | 13.01 | 9.14 | 17.55 | 2.73 | 2 | 20 | 2 |
| 73 | 880000. | 868000. | 736000. | 79. | 78. | 66. | 18.50 | 18.25 | 15.48 | 23.35 | 2.73 | 2 | 20 | 2 |
| 4204000 LITTLE CUYAHOGA RIVER AT MOGADORE, OHIO | | | | | | | | | | | | | | |
| 63 | 353000. | 359000. | 324000. | 77. | 78. | 71. | 7.43 | 7.55 | 6.81 | 9.65 | 1.70 | 2 | 20 | 1 |
| 67 | 513000. | 500000. | 477000. | 86. | 84. | 80. | 10.80 | 10.51 | 10.04 | 12.49 | 1.70 | 2 | 20 | 1 |
| 73 | 770000. | 767000. | 731000. | 90. | 89. | 85. | 16.19 | 16.13 | 15.36 | 18.05 | 1.77 | 2 | 20 | 1 |
| 4204500 LITTLE CUYAHOGA RIVER AT MASSILON ROAD, AKRON, OH. | | | | | | | | | | | | | | |
| 63 | 287000. | 292000. | 273000. | 82. | 83. | 78. | 6.05 | 6.14 | 5.75 | 7.38 | 1.99 | 2 | 20 | 2 |
| 67 | 399000. | 398000. | 379000. | 85. | 84. | 80. | 8.40 | 8.37 | 7.97 | 9.93 | 1.99 | 2 | 20 | 2 |
| 73 | 729000. | 734000. | 708000. | 86. | 87. | 84. | 15.33 | 15.42 | 14.88 | 17.75 | 1.99 | 2 | 20 | 2 |
| 4205000 SPRINGFIELD LAKE OUTLET AT AKRON, OHIO | | | | | | | | | | | | | | |
| 63 | 140000. | 139000. | 118000. | 77. | 76. | 65. | 2.95 | 2.93 | 2.49 | 3.84 | 1.58 | 2 | 20 | 2 |
| 67 | 190000. | 193000. | 186000. | 77. | 78. | 75. | 4.00 | 4.06 | 3.91 | 5.18 | 1.58 | 2 | 20 | 2 |
| 73 | 439000. | 444000. | 429000. | 77. | 78. | 75. | 9.24 | 9.33 | 9.02 | 11.96 | 1.58 | 2 | 20 | 2 |
| 4206000 CUYAHOGA RIVER AT OLD PORTAGE, OHIO | | | | | | | | | | | | | | |
| 63 | 286000. | 283000. | 215000. | 69. | 69. | 52. | 6.01 | 5.96 | 4.54 | 8.69 | 3.32 | 2 | 20 | 2 |
| 67 | 411000. | 406000. | 315000. | 69. | 68. | 53. | 8.63 | 8.54 | 6.63 | 12.51 | 3.32 | 2 | 20 | 2 |
| 73 | 689000. | 698000. | 613000. | 76. | 77. | 68. | 14.48 | 14.67 | 12.88 | 19.05 | 3.32 | 2 | 20 | 2 |

TABLE 5-12. RECHARGE STATISTICS, CUYAHOGA RIVER TO CONNEAUT CREEK BASINS

TABLE 5-12 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4207200 TINKERS CREEK AT BEDFORD, OHIO | | | | | | | | | | | | | | |
| 63 | 378000. | 369000. | 362000. | 67. | 66. | 64. | 7.95 | 7.76 | 7.61 | 11.83 | 2.43 | 2 | 13 | 3 |
| 67 | 369000. | 400000. | 325000. | 50. | 54. | 44. | 7.77 | 8.42 | 6.84 | 15.68 | 2.43 | 2 | 13 | 3 |
| 73 | 604000. | 613000. | 567000. | 52. | 53. | 49. | 12.71 | 12.88 | 11.92 | 24.38 | 2.43 | 2 | 13 | 3 |
| 4208000 CUYAHOGA RIVER AT INDEPENDENCE, OHIO | | | | | | | | | | | | | | |
| 63 | 320000. | 340000. | 312000. | 61. | 65. | 59. | 6.73 | 7.15 | 6.57 | 11.06 | 3.71 | 2 | 30 | 3 |
| 67 | 380000. | 386000. | 361000. | 61. | 62. | 58. | 7.99 | 8.12 | 7.60 | 13.12 | 3.71 | 2 | 30 | 3 |
| 73 | 704000. | 713000. | 678000. | 68. | 69. | 65. | 14.79 | 14.99 | 14.26 | 21.79 | 3.71 | 2 | 30 | 3 |
| 4208502 BIG CREEK AT CLEVELAND, OHIO | | | | | | | | | | | | | | |
| 73 | 334000. | 331000. | 320000. | 39. | 39. | 38. | 7.03 | 6.96 | 6.74 | 17.93 | 2.04 | 2 | 30 | 3 |
| 4209000 CHAGRIN RIVER AT WILLOUGHBY, OHIO | | | | | | | | | | | | | | |
| 63 | 322000. | 358000. | 331000. | 46. | 51. | 47. | 6.77 | 7.54 | 6.96 | 14.76 | 3.01 | 2 | 30 | 3 |
| 67 | 296000. | 317000. | 320000. | 39. | 42. | 42. | 6.22 | 6.67 | 6.74 | 16.03 | 3.01 | 2 | 30 | 3 |
| 73 | 504000. | 500000. | 484000. | 46. | 45. | 44. | 10.60 | 10.52 | 10.18 | 23.21 | 3.01 | 2 | 30 | 3 |
| 4211000 ROCK CREEK NEAR ROCK CREEK, OHIO | | | | | | | | | | | | | | |
| 63 | 121000. | 133000. | 111000. | 42. | 46. | 38. | 2.54 | 2.81 | 2.34 | 6.10 | 2.33 | 2 | 13 | 3 |
| 4211500 MILL CREEK NEAR JEFFERSON, OHIO | | | | | | | | | | | | | | |
| 63 | 217000. | 241000. | 156000. | 41. | 46. | 30. | 4.56 | 5.07 | 3.28 | 11.11 | 2.41 | 2 | 13 | 3 |
| 67 | 262000. | 289000. | 286000. | 30. | 33. | 32. | 5.51 | 6.09 | 6.28 | 18.32 | 2.41 | 2 | 13 | 3 |
| 73 | 343000. | 365000. | 325000. | 34. | 36. | 32. | 7.22 | 7.68 | 6.83 | 21.16 | 2.41 | 2 | 13 | 3 |

TABLE 5-12 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 4212000 GRAND RIVER NEAR MADISON, OHIO | | | | | | | | | | | | | | |
| 63 | 198000. | 194000. | 136000. | 47. | 46. | 33. | 4.16 | 4.08 | 2.86 | 8.80 | 3.57 | 2 | 30 | 3 |
| 67 | 278000. | 307000. | 226000. | 34. | 38. | 28. | 5.84 | 6.47 | 4.76 | 17.23 | 3.57 | 2 | 30 | 3 |
| 73 | 455000. | 463000. | 406000. | 46. | 47. | 41. | 9.56 | 9.73 | 8.53 | 20.85 | 3.57 | 2 | 30 | 3 |
| 4212500 ASHTABULA RIVER NEAR ASHTABULA, OHIO | | | | | | | | | | | | | | |
| 63 | 312000. | 324000. | 282000. | 52. | 54. | 47. | 6.57 | 6.81 | 5.92 | 12.72 | 2.61 | 2 | 30 | 3 |
| 67 | 282000. | 312000. | 322000. | 33. | 36. | 37. | 5.93 | 6.57 | 7.30 | 18.03 | 2.61 | 2 | 30 | 3 |
| 73 | 332000. | 354000. | 321000. | 35. | 37. | 33. | 6.99 | 7.44 | 6.76 | 20.19 | 2.61 | 2 | 30 | 3 |
| 4213000 CONNEAUT CREEK AT CONNEAUT, OHIO | | | | | | | | | | | | | | |
| 63 | 324000. | 338000. | 306000. | 48. | 50. | 45. | 6.81 | 7.10 | 6.43 | 14.24 | 2.81 | 2 | 30 | 3 |
| 67 | 369000. | 392000. | 387000. | 36. | 38. | 37. | 7.75 | 8.25 | 8.59 | 21.52 | 2.81 | 2 | 30 | 3 |
| 73 | 490000. | 508000. | 465000. | 45. | 47. | 43. | 10.30 | 10.68 | 9.78 | 22.93 | 2.81 | 2 | 30 | 3 |

CUYAHOGA BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 4202000 CUYAHOGA RIVER AT HIRAM RAPIDS, OHIO | | | | | | | | | | | | |
| FX | 219000. | 385000. | 871000. | 474000. | 881000. | 1314000. | 1106000. | 1277000. | 342000. | 331000. | 290000. | 119000. |
| SL | 212000. | 391000. | 768000. | 453000. | 831000. | 1434000. | 1042000. | 1221000. | 346000. | 314000. | 291000. | 124000. |
| LM | 187000. | 293000. | 331000. | 433000. | 655000. | 1096000. | 908000. | 421000. | 291000. | 221000. | 273000. | 123000. |
| 73 | | | | | | | | | | | | |
| FX | 559000. | 1258000. | 1040000. | 731000. | 762000. | 1912000. | 1414000. | 1168000. | 1206000. | 189000. | 142000. | 139000. |
| SL | 556000. | 1177000. | 1113000. | 775000. | 748000. | 1793000. | 1350000. | 1171000. | 1271000. | 189000. | 144000. | 139000. |
| LM | 281000. | 1144000. | 990000. | 667000. | 615000. | 1546000. | 1241000. | 985000. | 898000. | 189000. | 140000. | 144000. |
| 63 4209000 CHAGRIN RIVER AT WILLOUGHBY, OHIO | | | | | | | | | | | | |
| FX | 216000. | 404000. | 442000. | 396000. | 308000. | 1023000. | 503000. | 255000. | 110000. | 69000. | 72000. | 54000. |
| SL | 284000. | 394000. | 447000. | 402000. | 303000. | 1369000. | 520000. | 271000. | 104000. | 63000. | 72000. | 54000. |
| LM | 313000. | 439000. | 404000. | 371000. | 288000. | 1045000. | 568000. | 248000. | 99000. | 64000. | 68000. | 54000. |
| 67 | | | | | | | | | | | | |
| FX | 86000. | 265000. | 389000. | 284000. | 381000. | 686000. | 584000. | 462000. | 147000. | 123000. | 71000. | 76000. |
| SL | 85000. | 281000. | 487000. | 269000. | 391000. | 727000. | 567000. | 586000. | 146000. | 123000. | 71000. | 69000. |
| LM | 87000. | 250000. | 284000. | 299000. | 370000. | 771000. | 534000. | 835000. | 153000. | 122000. | 70000. | 65000. |
| 73 | | | | | | | | | | | | |
| FX | 291000. | 678000. | 727000. | 401000. | 490000. | 1084000. | 679000. | 712000. | 442000. | 196000. | 164000. | 182000. |
| SL | 278000. | 682000. | 740000. | 403000. | 501000. | 1116000. | 688000. | 657000. | 438000. | 197000. | 165000. | 135000. |
| LM | 263000. | 695000. | 702000. | 424000. | 453000. | 1064000. | 721000. | 577000. | 402000. | 198000. | 171000. | 139000. |
| 63 4212000 GRAND RIVER NEAR MADISON, OHIO | | | | | | | | | | | | |
| FX | 27000. | 161000. | 267000. | 265000. | 112000. | 1030000. | 364000. | 76000. | 41000. | 6882. | 7603. | 1865. |
| SL | 32000. | 153000. | 284000. | 277000. | 109000. | 984000. | 348000. | 74000. | 37000. | 6279. | 7751. | 1839. |
| LM | 19000. | 135000. | 242000. | 253000. | 107000. | 406000. | 356000. | 72000. | 26000. | 4108. | 4943. | 1688. |
| 67 | | | | | | | | | | | | |
| FX | 14000. | 176000. | 453000. | 347000. | 330000. | 867000. | 500000. | 473000. | 35000. | 46000. | 35000. | 44000. |
| SL | 14000. | 205000. | 572000. | 354000. | 363000. | 833000. | 486000. | 717000. | 35000. | 51000. | 34000. | 12000. |
| LM | 12000. | 173000. | 262000. | 338000. | 311000. | 609000. | 454000. | 428000. | 35000. | 45000. | 34000. | 12000. |
| 73 | | | | | | | | | | | | |
| FX | 114000. | 605000. | 677000. | 395000. | 398000. | 1465000. | 768000. | 560000. | 371000. | 28000. | 52000. | 15000. |
| SL | 143000. | 695000. | 736000. | 382000. | 386000. | 1498000. | 759000. | 523000. | 343000. | 28000. | 41000. | 12000. |
| LM | 89000. | 645000. | 692000. | 369000. | 337000. | 1329000. | 628000. | 389000. | 326000. | 35000. | 12000. | 10600. |

TABLE 5-13. MONTHLY RECHARGE RATES, CUYAHOGA RIVER TO CONNEAUT CREEK BASINS

and gravels that make up scattered high-level terraces, kames, kame terraces, and buried valleys. End moraines are also very complex and contain interbedded sands, gravels, and clay-silt tills. Areas covered by till, which ranges from a few feet to over 200 feet in thickness, usually yield very little water because of their dense, fine-grained character.

Well yields range from very small in the Lake Plain, to 5 to 25 gpm from sandstones and fractured shales, to 25 to 100 gpm in sands and gravels, while a few scattered localities yield as much as 1000 gpm.

Annual precipitation in the region is high when compared to the rest of the State. During 1963, 1967, and 1973, precipitation ranged from 25 to 30, 30 to 45, and 35 to 40 inches, respectively.

The highest streamflows occur during early spring, generally March and April. Flow is lowest during late summer and many smaller streams are dry. During 1963, some of the larger streams showed very low flows. For the Cuyahoga, Chagrin, Grand, Ashtabula, and Conneaut, respectively, the 90 percent flow during 1967 was 0.29, 0.14, 0.03, 0.04, and 0.14 cfs/sq. mi. respectively.

The separation of hydrographs for each of the streams indicates the wide variety of stream characteristics that exist in this region. Most of the stations on the Cuyahoga are controlled. The Cuyahoga River Valley, including Akron and Cleveland, is one of the most heavily industrialized region in the country. Because of this, effective recharge rates based on stream hydrograph separation are not reliable.

The Chagrin River flows on bedrock in some places and on valley fill in others. Effective recharge rates appear to be high as well as flow duration ratios (Table 5-12). It has been suggested that the high sustained low flow is a result of discharge from conglomerate and sandstone units that crop out along its deeply incised valley. Most flow ratios indicate that the sustained flow of the Grand and Ashtabula Rivers is very low. Recharge rates for tributaries are in the range of less than 100,000 to 200,000 gpd/sq. mi., but stations near the mouth indicate higher rates. It is estimated that influences from industrialization and urbanization have regulated the hydrograph during the wetter part of the year. This would not affect the low-flow indices, but would affect the hydrograph separation. Conneaut Creek shows abnormally high low-flow indices as well as high effective recharge rates. It is not known what the controlling factors affecting the flow characteristics in this stream may be. It is similar in geology and physiography to the west of the Lake Plain and should have very low flow indices. Communities in the area have a very hard time locating ground water supplies in the clay till and shale bedrock. Apart from scattered beach ridges, most persons must obtain city water taken from Lake Erie.

The chemical quality of the ground water in the zone of intensive circulation is usually moderately hard in the glacial materials, usually from 100 to 200 mg/l, with dissolved solids ranging from 200 to 300 mg/l. Near surface water in the bedrock is quite variable because of the control of water movement by fracture systems. Iron is locally high in water from glacial materials or bedrock. Stream pollution in this region, some of the worst in the State, renders much of the valley fill deposits useless as aquifers. Contrary to other areas of the State, it is often much more economical to export processed lake water to communities that border the industrialized areas. In the upper reaches of the streams, though, vast quantities of good quality water can be obtained from the uncontaminated buried valleys.

## Mahoning River

The heavily industrialized Mahoning River Basin is entirely within the Glaciated Plateau (Fig. 5-8). The river is about 108 miles long and drains 1133 square miles. Major tributaries include Mill Creek (80 sq. mi. basin), Mosquito Creek (139 sq. mi.), Eagle Creek (109 sq. mi.), West Branch (109 sq. mi.) and

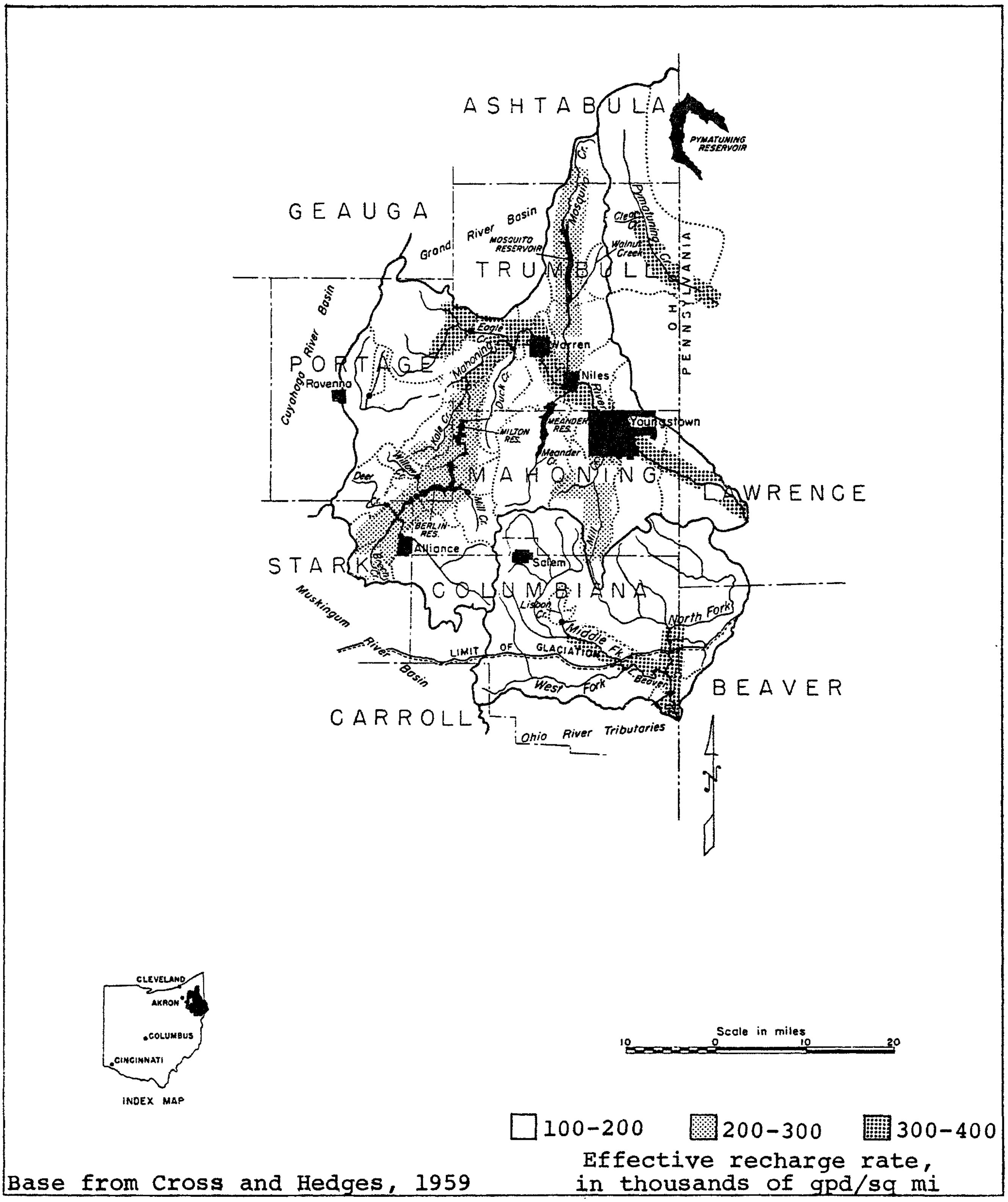



FIGURE 5-8. EFFECTIVE RECHARGE RATES IN THE MAHONING RIVER AND LITTLE BEAVER CREEK BASINS

Kale Creek (24 sq. mi.). Two other adjoining basins of similar characteristics are Pymatuning Creek (174 sq. mi.) in the Shenango River Basin and Little Beaver Creek (510 sq. mi.).

The average gradient of the Mahoning River is 4 feet per mile. Tributaries entering from the north have moderate gradients of 6 to 7 ft/mi., whereas those from the south and west have higher gradients (11 to 18 ft/mi.). Little Beaver Creek, 52 miles long, also has a high gradient (9.6 ft/mi.) for a moderately large basin.

Bedrock ranges from the Berea Sandstone of Mississippian age to the Pottsville and Allegheny Formations of Pennsylvanian age. Interbedded sandstone and shale are common in the Mississippian section and Pennsylvanian cyclothems crop out as alternating sequences of conglomerate, sandstone, shale, clay, coal, and limestone. Even though several of these units are used locally as a source of water, low flow indices indicate they contribute negligible water to base flow.

Glacial drift in the area is both erratic in thickness and variable in character. Clayey till, averaging 25 feet in thickness, covers most of the basin. Buried valleys, which may exceed 150 feet in depth, generally contain clay and fine sand, but small localized deposits are much coarser. The western part of the basin has thick end moraines. Very little water can be expected to be contributed by a majority of the glacial deposits.

Well yields range from less than 5 gpm from the glacial till to more than 500 gpm in a small well sorted sand and gravel deposit in a preglacial valley near Alliance. Most areas in the basin yield from 5 to 25 gpm and are developed in thin sand lenses or underlying sandstones and shale. Some areas have yields that range between 25 and 100 gpm from thicker lenses of sand and gravel or sandstone and shale that have extensive fractures.

Because of this low yield of wells over most of the basin, numerous surface water reservoirs and control structures are present. Flow indices and effective recharge rates both reflect the large amount of control exerted in this basin (Table 5-14 and 5-15).

Precipitation in this basin for 1963, 1967, and 1973 ranged from 30 to 35, 30 to 40, and 35 to 40 inches, respectively. Precipitation patterns were similar during 1963 and 1973, which averaged about 30 inches in 1963 and 38 inches in 1973. On the other hand 1967 was quite different. Precipitation was unevenly distributed between two high precipitation zones in the northern and southern parts of the basin. The basin as a whole is about average in amount of total precipitation, but its distribution is not similar to the 1931-60 average pattern.

Highest flows usually occur during the spring. Over most of the basin, the year 1967 averaged similarily to the 1931-1960 average yearly amount, but the March runoff was much lower than even 1963. The May, 1967, runoff was much greater than the flows in both 1963 and 1973, equalizing the annual amount. Since precipitation and streamflow during 1967 are anomalous, this particular year is not representative of normal flow in this basin, but to maintain uniformity with other parts of the State, it was used but reservations are made as to its applicability.

In most years the lowest flows occur from middle summer to late fall and many of the smaller streams are completely dry towards the end of the water year. Very low flows are common, even on the larger uncontrolled streams. During 1967, the 90 percent flow was 0.015, 0.003, and 0.93 cfs/sq. mi. for Mill, Kale and Little Beaver Creeks, respectively (Table 5-16).

Recharge rates from hydrograph separations in this basin are anomalously high in comparison to the low-flow indices and the nature of the near surface materials. Since hydrograph separation as well as flow-duration curves depend on separating storage in the basin from direct runoff, the large amount of control exerted by dams and reservoirs is probably the governing factor. Since many of the reservoirs serve as water supplies, the control they exert is greatest during

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3086500 MAHONING RIVER AT ALLIANCE, OHIO | | | | | | | | | | | | | | |
| 63 | 199000. | 184000. | 168000. | 51. | 47. | 43. | 4.19 | 3.88 | 3.56 | 8.29 | 2.46 | 2 | 11 | 1 |
| 67 | 269000. | 275000. | 268000. | 47. | 48. | 48. | 5.67 | 5.79 | 5.71 | 11.95 | 2.46 | 2 | 11 | 1 |
| 73 | 464000. | 463000. | 457000. | 53. | 52. | 52. | 9.76 | 9.73 | 9.63 | 18.56 | 2.46 | 2 | 11 | 1 |
| 3089500 MILL CREEK NEAR BERLIN CENTER, OHIO | | | | | | | | | | | | | | |
| 63 | 162000. | 173000. | 115000. | 49. | 53. | 35. | 3.41 | 3.64 | 2.43 | 6.89 | 1.80 | 2 | 11 | 1 |
| 67 | 186000. | 202000. | 141000. | 39. | 42. | 29. | 3.92 | 4.24 | 2.98 | 10.12 | 1.80 | 2 | 11 | 1 |
| 3090500 MAHONING RIVER BELOW BERLIN DAM, NEAR BERLIN CENTER, | | | | | | | | | | | | | | |
| 63 | 232000. | 233000. | 222000. | 71. | 71. | 67. | 4.88 | 4.90 | 4.67 | 6.92 | 3.01 | 2 | 11 | 1 |
| 67 | 258000. | 242000. | 209000. | 52. | 49. | 42. | 5.42 | 5.09 | 4.40 | 10.44 | 3.01 | 2 | 11 | 1 |
| 73 | 641000. | 675000. | 632000. | 72. | 76. | 71. | 13.46 | 14.19 | 13.28 | 18.78 | 3.01 | 2 | 11 | 1 |
| 3091500 MAHONING RIVER AT PRICETOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 273000. | 280000. | 266000. | 83. | 85. | 81. | 5.75 | 5.90 | 5.59 | 6.91 | 3.07 | 2 | 11 | 1 |
| 67 | 255000. | 260000. | 234000. | 53. | 54. | 49. | 5.38 | 5.48 | 4.93 | 10.13 | 3.07 | 2 | 11 | 1 |
| 73 | 746000. | 755000. | 616000. | 82. | 83. | 67. | 15.67 | 15.86 | 12.95 | 19.20 | 3.07 | 2 | 11 | 1 |
| 3092000 KALE CREEK NEAR PRICETOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 151000. | 159000. | 111000. | 47. | 50. | 35. | 3.17 | 3.35 | 2.34 | 6.75 | 1.85 | 2 | 11 | 1 |
| 67 | 238000. | 252000. | 191000. | 43. | 45. | 34. | 5.01 | 5.30 | 4.02 | 11.68 | 1.85 | 2 | 11 | 1 |
| 73 | 365000. | 377000. | 313000. | 41. | 42. | 35. | 7.68 | 7.93 | 6.58 | 18.74 | 1.85 | 2 | 11 | 1 |

TABLE 5-14. RECHARGE STATISTICS, MAHONING RIVER AND LITTLE BEAVER CREEK BASINS

TABLE 5-14 CONTINUED

| YR | RECHARGE RATE, GPD/SQ.MI. FIXED | SLIDING | LOCMIN | GW, PERCENT FX | SL | LM | GW, IN INCHES FX | SL | LM | DIS IN | N DAYS | GEOLOGY REL | SUR | BRK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3092090 WEST BRANCH MAHONING RIVER NEAR RAVENNA, OHIO | | | | | | | | | | | | | | |
| 67 | 366000. | 349000. | 330000. | 59. | 56. | 53. | 7.70 | 7.35 | 6.95 | 13.10 | 1.85 | 2 | 11 | 1 |
| 73 | 547000. | 551000. | 479000. | 58. | 58. | 50. | 11.51 | 11.58 | 10.06 | 19.95 | 1.85 | 2 | 11 | 1 |
| 3092460 WEST BRANCH MAHONING R. BELOW KIRWAN DAM, WAYLAND, OHIO | | | | | | | | | | | | | | |
| 73 | 757000. | 791000. | 696000. | 79. | 83. | 73. | 15.92 | 16.63 | 14.63 | 20.07 | 2.41 | 2 | 11 | 1 |
| 3092500 WEST BRANCH MAHONING RIVER NEAR NEWTON FALLS, OHIO | | | | | | | | | | | | | | |
| 63 | 260000. | 263000. | 253000. | 53. | 54. | 52. | 5.47 | 5.54 | 5.34 | 10.27 | 2.49 | 2 | 11 | 1 |
| 67 | 184000. | 185000. | 183000. | 68. | 68. | 67. | 3.88 | 3.90 | 3.84 | 5.74 | 2.49 | 2 | 11 | 1 |
| 73 | 690000. | 715000. | 647000. | 78. | 81. | 73. | 14.50 | 15.02 | 13.61 | 18.55 | 2.49 | 2 | 11 | 1 |
| 3093000 EAGLE CREEK AT PHALANX STATION, OHIO | | | | | | | | | | | | | | |
| 63 | 268000. | 283000. | 265000. | 59. | 62. | 58. | 5.63 | 5.95 | 5.58 | 9.57 | 2.50 | 2 | 11 | 2 |
| 67 | 325000. | 337000. | 331000. | 51. | 53. | 52. | 6.83 | 7.09 | 7.29 | 13.37 | 2.50 | 2 | 11 | 2 |
| 73 | 544000. | 545000. | 507000. | 59. | 59. | 55. | 11.44 | 11.46 | 10.67 | 19.49 | 2.50 | 2 | 11 | 2 |
| 3094000 MAHONING RIVER AT LEAVITTSBURG, OHIO | | | | | | | | | | | | | | |
| 63 | 249000. | 264000. | 260000. | 68. | 72. | 71. | 5.25 | 5.55 | 5.48 | 7.71 | 3.56 | 2 | 11 | 2 |
| 67 | 320000. | 310000. | 286000. | 67. | 65. | 60. | 6.73 | 6.52 | 6.01 | 10.07 | 3.56 | 2 | 11 | 2 |
| 73 | 655000. | 666000. | 651000. | 75. | 76. | 75. | 13.76 | 14.01 | 13.68 | 18.31 | 3.56 | 2 | 11 | 2 |
| 3095500 MOSQUITO CREEK BELOW MOSQUITO CREEK DAM, NEAR CORTLAN | | | | | | | | | | | | | | |
| 63 | 198000. | 198000. | 198000. | 85. | 84. | 85. | 4.17 | 4.16 | 4.17 | 4.93 | 2.50 | 2 | 13 | 2 |
| 67 | 248000. | 243000. | 216000. | 66. | 65. | 58. | 5.21 | 5.12 | 4.55 | 7.88 | 2.50 | 2 | 13 | 2 |
| 73 | 554000. | 553000. | 496000. | 75. | 75. | 68. | 11.64 | 11.63 | 10.43 | 15.44 | 2.50 | 2 | 13 | 2 |

TABLE 5-14 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3098000 MAHONING RIVER AT YOUNGSTOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 253000. | 260000. | 268000. | 73. | 75. | 77. | 5.33 | 5.48 | 5.63 | 7.34 | 3.90 | 2 | 11 | 2 |
| 67 | 323000. | 320000. | 313000. | 63. | 63. | 61. | 6.79 | 6.73 | 6.58 | 10.70 | 3.90 | 2 | 11 | 2 |
| 73 | 645000. | 664000. | 656000. | 72. | 74. | 73. | 13.56 | 13.95 | 13.78 | 18.89 | 3.90 | 2 | 11 | 2 |
| 3098500 MILL CREEK AT YOUNGSTOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 130000. | 140000. | 14000. | 40. | 42. | 41. | 2.80 | 3.00 | 0.30 | 7.20 | 3.67 | 2 | 11 | 2 |
| 67 | 255000. | 258000. | 254000. | 50. | 50. | 49. | 5.37 | 5.44 | 5.34 | 10.80 | 2.31 | 2 | 11 | 2 |
| 3099500 MAHONING RIVER AT LOWELLVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 257000. | 262000. | 244000. | 71. | 72. | 67. | 5.41 | 5.52 | 5.53 | 7.66 | 4.04 | 2 | 11 | 2 |
| 67 | 314000. | 319000. | 285000. | 61. | 62. | 56. | 6.61 | 6.70 | 6.75 | 10.78 | 4.04 | 2 | 11 | 2 |
| 73 | 623000. | 634000. | 616000. | 71. | 72. | 70. | 13.09 | 13.32 | 13.48 | 18.54 | 4.04 | 2 | 11 | 2 |
| 3102950 PYMATUMING CREEK AT KINSMAN, OHIO | | | | | | | | | | | | | | |
| 67 | 420000. | 409000. | 322000. | 63. | 62. | 49. | 8.82 | 8.61 | 6.77 | 13.94 | 2.50 | 2 | 11 | 2 |
| 73 | 579000. | 564000. | 449000. | 65. | 64. | 51. | 12.17 | 11.87 | 9.44 | 18.66 | 2.50 | 2 | 11 | 2 |
| 3109500 LITTLE BEAVER CREEK NEAR EAST LIVERPOOL, OHIO | | | | | | | | | | | | | | |
| 63 | 234000. | 235000. | 228000. | 56. | 56. | 54. | 4.93 | 4.94 | 4.79 | 8.84 | 3.46 | 3 | 13 | 1 |
| 67 | 311000. | 315000. | 318000. | 58. | 59. | 59. | 6.55 | 6.62 | 6.80 | 11.22 | 3.46 | 3 | 13 | 1 |
| 73 | 579000. | 588000. | 563000. | 62. | 63. | 60. | 12.17 | 12.36 | 11.83 | 19.71 | 3.46 | 3 | 13 | 1 |

MAHONING-LITTLE BEAVER BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 3089500 MILL CREEK NEAR BERLIN CENTER, OHIO | | | | | | | | | | | | |
| FX | 23000. | 25000. | 40000. | 49000. | 72000. | 1250000. | 257000. | 88000. | 90000. | 14000. | 10000. | 6926. |
| SL | 23000. | 26000. | 39000. | 51000. | 72000. | 1353000. | 293000. | 96000. | 66000. | 18000. | 10000. | 7613. |
| LM | 23000. | 23000. | 32000. | 42000. | 56000. | 762000. | 290000. | 77000. | 43000. | 13000. | 10000. | 7021. |
| 67 | | | | | | | | | | | | |
| FX | 12000. | 42000. | 140000. | 57000. | 294000. | 833000. | 301000. | 500000. | 24000. | 8361. | 8776. | 14000. |
| SL | 12000. | 40000. | 146000. | 61000. | 287000. | 865000. | 308000. | 638000. | 24000. | 9900. | 9714. | 14000. |
| LM | 11000. | 25000. | 148000. | 59000. | 188000. | 467000. | 290000. | 455000. | 25000. | 7410. | 7719. | 9961. |
| 63 3092000 KALE CREEK NEAR PRICETOWN, OHIO | | | | | | | | | | | | |
| FX | 24000. | 35000. | 45000. | 49000. | 76000. | 1193000. | 260000. | 65000. | 26000. | 8187. | 8187. | 3049. |
| SL | 25000. | 43000. | 42000. | 49000. | 75000. | 1247000. | 288000. | 75000. | 23000. | 11000. | 8232. | 3246. |
| LM | 27000. | 27000. | 31000. | 39000. | 64000. | 827000. | 235000. | 45000. | 12000. | 7662. | 8256. | 3313. |
| 67 | | | | | | | | | | | | |
| FX | 1875. | 86000. | 291000. | 92000. | 514000. | 806000. | 369000. | 673000. | 14000. | 10000. | 2361. | 13000. |
| SL | 1875. | 74000. | 328000. | 113000. | 377000. | 916000. | 365000. | 805000. | 15000. | 10900. | 2313. | 12000. |
| LM | 1384. | 20000. | 317000. | 91000. | 195000. | 707000. | 360000. | 562000. | 15000. | 9116. | 2334. | 2788. |
| 73 | | | | | | | | | | | | |
| FX | 71000. | 257000. | 754000. | 231000. | 327000. | 1395000. | 607000. | 481000. | 127000. | 37000. | 40000. | 40000. |
| SL | 71000. | 272000. | 761000. | 224000. | 349000. | 1389000. | 674000. | 528000. | 128000. | 42000. | 38000. | 31000. |
| LM | 74000. | 141000. | 614000. | 164000. | 252000. | 1419000. | 529000. | 321000. | 134000. | 35000. | 31000. | 21000. |
| 63 3109500 LITTLE BEAVER CREEK NEAR EAST LIVERPOOL, OHIO | | | | | | | | | | | | |
| FX | 62000. | 108000. | 117000. | 153000. | 138000. | 1250000. | 432000. | 248000. | 137000. | 57000. | 54000. | 38000. |
| SL | 62000. | 103000. | 120000. | 159000. | 139000. | 1217000. | 465000. | 244000. | 138000. | 59000. | 58000. | 39000. |
| LM | 62000. | 96000. | 118000. | 164000. | 119000. | 1152000. | 438000. | 261000. | 144000. | 60000. | 60000. | 41000. |
| 67 | | | | | | | | | | | | |
| FX | 47000. | 116000. | 213000. | 107000. | 304000. | 996000. | 725000. | 859000. | 154000. | 77000. | 63000. | 66000. |
| SL | 49000. | 117000. | 227000. | 111000. | 338000. | 959000. | 698000. | 954000. | 149000. | 75000. | 61000. | 63000. |
| LM | 47000. | 121000. | 141000. | 113000. | 245000. | 967000. | 690000. | 1154000. | 183000. | 77000. | 62000. | 64000. |
| 73 | | | | | | | | | | | | |
| FX | 181000. | 641000. | 1110000. | 552000. | 575000. | 1098000. | 1040000. | 931000. | 426000. | 148000. | 144000. | 97000. |
| SL | 179000. | 676000. | 1155000. | 566000. | 566000. | 1104000. | 1051000. | 951000. | 422000. | 144000. | 148000. | 88000. |
| LM | 183000. | 696000. | 1163000. | 584000. | 475000. | 1000000. | 971000. | 824000. | 444000. | 150000. | 174000. | 80000. |

TABLE 5-15. MONTHLY RECHARGE RATES, MAHONING RIVER AND LITTLE BEAVER CREEK BASINS

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3086500 MAHONING RIVER AT ALLIANCE,OHIO | | | | | | | | | |
| 73 | 4.98330 | 2.44949 | 0.12332 | 0.13453 | 0.29148 | 0.63901 | 0.91368 | 0 | 0 |
| 67 | 6.46930 | 2.95039 | 0.05045 | 0.06054 | 0.09305 | 0.16816 | 0.22982 | 0 | 0 |
| 63 | 4.86400 | 1.80361 | 0.03251 | 0.04596 | 0.09305 | 0.13453 | 0.15695 | 0 | 0 |
| 3089500 MILL CREEK NEAR BERLIN CENTER, OHIO | | | | | | | | | |
| 63 | 7.30297 | 2.18899 | 0.01047 | 0.01571 | 0.03141 | 0.05236 | 0.06283 | 0 | 0 |
| 67 | 10.52208 | 4.44444 | 0.01152 | 0.01466 | 0.02120 | 0.04188 | 0.07068 | 0 | 0 |
| 3090500 MAHONING RIVER BELOW BERLIN DAM, NEAR BERLIN CENTER, O. | | | | | | | | | |
| 63 | 3.81608 | 3.24491 | 0.06452 | 0.06452 | 0.06855 | 0.22177 | 0.31855 | 0 | 0 |
| 67 | 3.75648 | 2.28834 | 0.02419 | 0.10887 | 0.14919 | 0.25806 | 0.46371 | 0 | 1 |
| 73 | 3.70270 | 1.64014 | 0.09274 | 0.20161 | 0.68952 | 0.95968 | 1.04839 | 0 | 0 |
| 3091500 MAHONING RIVER AT PRICETOWN, OHIO | | | | | | | | | |
| 63 | 2.26849 | 1.86848 | 0.12088 | 0.16300 | 0.20879 | 0.27839 | 0.31502 | 0 | 0 |
| 67 | 4.42766 | 1.80151 | 0.06593 | 0.08791 | 0.20147 | 0.32967 | 0.49084 | 0 | 0 |
| 73 | 2.69098 | 1.90830 | 0.27839 | 0.42491 | 0.63370 | 0.86081 | 0.93407 | 0 | 0 |
| 3092000 KALE CREEK NEAR PRICETOWN, OHIO | | | | | | | | | |
| 63 | 10.24695 | 2.81736 | 0.00457 | 0.00913 | 0.01826 | 0.03653 | 0.06393 | 0 | 5 |
| 67 | 28.72281 | 8.16497 | 0.00228 | 0.00274 | 0.00822 | 0.03425 | 0.07763 | 0 | 0 |
| 73 | 9.17011 | 4.14997 | 0.03014 | 0.04018 | 0.08219 | 0.26027 | 0.40183 | 0 | 0 |

TABLE 5-16. FLOW-RATIO STATISTICS, MAHONING RIVER AND LITTLE BEAVER CREEK BASINS

TABLE 5-16 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3092090 WEST BRANCH MAHONING RIVER NEAR RAVENNA, OHIO | | | | | | | | | |
| 67 | 6.56330 | 3.08957 | 0.05046 | 0.05963 | 0.10092 | 0.17431 | 0.29817 | 0 | 0 |
| 73 | 5.70964 | 2.72888 | 0.10092 | 0.11468 | 0.21560 | 0.59633 | 0.82569 | 0 | 0 |
| 3092460 WEST BRANCH MAHONING R. BELOW KIRWAN DAM,WAYLAND,OHIO | | | | | | | | | |
| 73 | 2.67862 | 1.91485 | 0.29376 | 0.48960 | 0.51408 | 0.84455 | 1.07711 | 0 | 0 |
| 3092500 WEST BRANCH MAHONING RIVER NEAR NEWTON FALLS, OHIO | | | | | | | | | |
| 63 | 4.09231 | 1.73205 | 0.07269 | 0.08619 | 0.11423 | 0.16615 | 0.19730 | 0 | 0 |
| 67 | 2.18386 | 1.74801 | 0.10177 | 0.13499 | 0.18692 | 0.24922 | 0.31153 | 0 | 0 |
| 73 | 2.46840 | 1.72494 | 0.38422 | 0.44652 | 0.63344 | 0.82035 | 0.99688 | 0 | 0 |
| 3093000 EAGLE CREEK AT PHALANX STATION, OHIO | | | | | | | | | |
| 63 | 3.86556 | 1.75412 | 0.08094 | 0.08914 | 0.13320 | 0.20492 | 0.25102 | 0 | 0 |
| 67 | 4.86335 | 2.33333 | 0.09426 | 0.11783 | 0.18443 | 0.26639 | 0.40984 | 0 | 0 |
| 73 | 4.08350 | 2.25770 | 0.17418 | 0.20492 | 0.36885 | 0.74795 | 0.99898 | 0 | 0 |
| 3094000 MAHONING RIVER AT LEAVITTSBURG, OHIO | | | | | | | | | |
| 63 | 2.07693 | 1.43136 | 0.18261 | 0.19130 | 0.21391 | 0.29913 | 0.39130 | 0 | 0 |
| 67 | 2.86674 | 1.46712 | 0.22087 | 0.23913 | 0.28522 | 0.39130 | 0.41565 | 0 | 0 |
| 73 | 2.34408 | 1.87965 | 0.47304 | 0.49217 | 0.55870 | 0.68522 | 0.86870 | 0 | 0 |
| 3095500 MOSQUITO CREEK BELOW MOSQUITO CREEK DAM, NEAR CORTLAND | | | | | | | | | |
| 63 | 5.86894 | 3.47926 | 0.03487 | 0.03692 | 0.03897 | 0.12308 | 0.19487 | 0 | 0 |
| 67 | 5.05329 | 3.47325 | 0.05744 | 0.05744 | 0.06462 | 0.07179 | 0.14872 | 0 | 0 |
| 73 | 3.22318 | 2.50891 | 0.15385 | 0.18462 | 0.28718 | 0.48205 | 0.83077 | 0 | 0 |

TABLE 5-16 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3098000 MAHONING RIVER AT YOUNGSTOWN, OHIO | | | | | | | | | |
| 63 | 1.96013 | 1.40468 | 0.20045 | 0.21158 | 0.23831 | 0.28285 | 0.35412 | 0 | 0 |
| 67 | 2.88544 | 1.49689 | 0.22717 | 0.24610 | 0.29844 | 0.37639 | 0.42483 | 0 | 0 |
| 73 | 2.50000 | 1.94293 | 0.44766 | 0.46771 | 0.52951 | 0.69265 | 1.00835 | 0 | 0 |
| 3098500 MILL CREEK AT YOUNGSTOWN, OHIO | | | | | | | | | |
| 63 | 4.86865 | 2.04124 | 0.00271 | 0.00407 | 0.00724 | 0.01086 | 0.01373 | 0 | 0 |
| 67 | 7.59554 | 3.04290 | 0.03167 | 0.03922 | 0.08145 | 0.13575 | 0.19608 | 0 | 0 |
| 3099500 MAHONING RIVER AT LOWELLVILLE, OHIO | | | | | | | | | |
| 63 | 2.02081 | 1.34580 | 0.22367 | 0.23392 | 0.26654 | 0.30941 | 0.36719 | 0 | 0 |
| 67 | 2.69418 | 1.49413 | 0.25629 | 0.27027 | 0.34483 | 0.39049 | 0.42311 | 0 | 0 |
| 73 | 2.35252 | 1.80915 | 0.46412 | 0.48835 | 0.56664 | 0.82013 | 1.07176 | 0 | 0 |
| 3102950 PYMATUMING CREEK AT KINSMAN, OHIO | | | | | | | | | |
| 67 | 8.12254 | 3.60208 | 0.02896 | 0.04240 | 0.10341 | 0.33092 | 0.51706 | 0 | 0 |
| 73 | 9.64019 | 4.59342 | 0.02896 | 0.03878 | 0.09876 | 0.45502 | 0.71355 | 0 | 0 |
| 3109500 LITTLE BEAVER CREEK NEAR EAST LIVERPOOL, OHIO | | | | | | | | | |
| 63 | 3.91675 | 1.92531 | 0.07258 | 0.08871 | 0.12550 | 0.18145 | 0.22177 | 0 | 0 |
| 67 | 5.00000 | 2.69590 | 0.08266 | 0.09274 | 0.14113 | 0.20363 | 0.27218 | 0 | 0 |
| 73 | 3.91836 | 2.49953 | 0.15323 | 0.19960 | 0.32157 | 0.84677 | 1.20060 | 0 | 0 |

dry periods, which would probably not greatly affect the low-flow indices, but would affect the generalized shape of the flow-duration curve and definitely would affect the hydrograph separation. The fact that some of the dams are also flood-control structures further affects the separation without materially changing the dry weather flow indices.

The range of flow separations that is reasonable for this area is from less than 100,000 gpd/sq. mi. to 300,000 gpd/sq. mi. Most of the basin has low permeability and a recharge rate as low as 100,000 gpd/sq. mi. is not unreasonable. Eagle Creek is a notable exception because it drains permeable glacial deposits and sandstone. Effective recharge rates for this stream exceed 300,000 gpd/sq. mi.

The chemical quality of near-surface ground-water depends, to a large degree, on the unit in which it is stored. Generally, water in the clayey till is hard and has a high concentration of iron. Water in the sandy till is moderately hard and also contains objectionable amounts of iron. Sand and gravel deposits yield water that may be hard but may or may not contain objectionable amounts of iron, while that from sandstones is hard, but does not contain much iron. Water from some sandstone units is very soft. Chloride tends to increase with depth, especially in the alternating sandstones and shales. Quality in all units varies depending upon how long the water has been in contact with the deposits. Because of this, water in shallow aquifers is often better than that obtained from higher producing deeper aquifers. Some problems may be expected in the southern Mahoning basin and the Little Beaver basin because of coal mining. Sulfate is one of the major problems. Areas near strip mine spoil banks, or near underground mine workings may produce objectionable water.

Most of the Little Beaver Creek basin is glaciated but part of the southern area lies in the unglaciated plateau, which has well dissected topography. Till, which covers most of the glaciated basin, ranges in thickness from a thin veneer to as much as 25 feet.

Wells developed in sandstone formations yield as much as 25 gpm but generally much less. Buried valley deposits, consisting of layers of fine sand interbedded with sand and gravel and clays yield 25 to 100 gpm. As much as 1000 gpm has been developed along the Ohio River valley in sand and gravel beneath shallow alluvium.

Annual precipitation in this basin ranged between 25 to 30, 30 to 45, and 35 to 40 inches in 1963, 1967 and 1973, respectively. The highest flows are in the early spring. Effective recharge is also the highest in March, April and May ranging from 690,000 in April 1967 to 1,154,000 in May 1967 for a year of normal precipitation.

Average effective recharge rates ranged from 228,000 gpd/sq. mi. in a dry year to 563,000 gpd/sq. mi. in a wet year. Chemical quality is similar to other areas of the Mahoning basin except for areas affected by strip mines.

## Ohio River Drainage, East Liverpool to Marietta

The streams that flow into the Ohio River between East Liverpool and Marietta drain about 2500 square miles (Fig. 5-9). Most are 20 to 30 miles long and include Yellow, Cross, Short, Wheeling, McMahon, Captina and Sunfish Creeks. At the south end of the area are Little Muskingum River and Duck Creek , both of which exceed 30 miles in length. For the most part, these streams drain an unglaciated region characterized by rugged topography, deep valleys and narrow gorges.

The region consists almost entirely of Pennsylvanian and Permian age strata composed of alternating layers of sandstone, shale and coal seams, with occasional layers of limestone. Many of the sandstones are relatively thick and form prominent cliffs, particularly along the margin of the Ohio River. Since 1804 coal

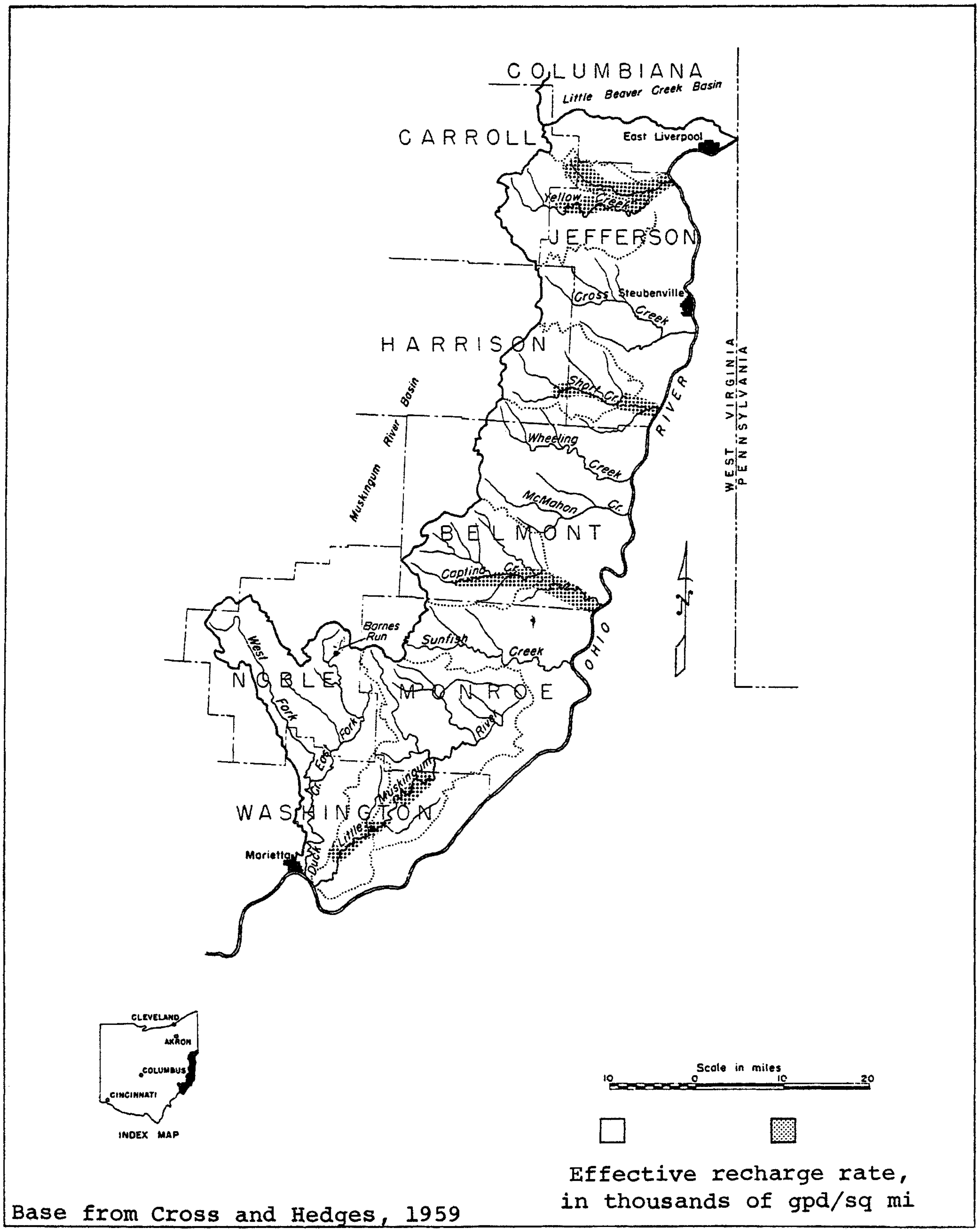



FIGURE 5-9. EFFECTIVE RECHARGE RATES, OHIO RIVER DRAINAGE BETWEEN EAST LIVERPOOL AND MARIETTA

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3110000 YELLOW CREEK NEAR HAMMONDSVILLE, OHIO, | | | | | | | | | |
| 63 | 6.96199 | 2.43443 | 0.01769 | 0.03333 | 0.11565 | 0.20408 | 0.31293 | 0 | 0 |
| 67 | 9.28191 | 4.09878 | 0.02789 | 0.03537 | 0.06803 | 0.13605 | 0.19048 | 0 | 0 |
| 73 | 5.12348 | 2.97435 | 0.08163 | 0.10884 | 0.21088 | 0.82993 | 1.15646 | 0 | 0 |
| 3111500 SHORT CREEK NEAR DILLONVALE, OHIO | | | | | | | | | |
| 63 | 3.19446 | 1.82574 | 0.15447 | 0.17886 | 0.23780 | 0.32520 | 0.42276 | 0 | 0 |
| 67 | 3.85357 | 2.34901 | 0.13821 | 0.16260 | 0.22764 | 0.30081 | 0.39837 | 0 | 0 |
| 73 | 3.13162 | 1.99105 | 0.15447 | 0.23171 | 0.39837 | 0.69106 | 0.91870 | 0 | 0 |
| 3114000 CAPTINA CREEK AT ARMSTRONG MILLS, OHIO | | | | | | | | | |
| 63 | 12.12435 | 4.38178 | 0.00746 | 0.01493 | 0.04664 | 0.16418 | 0.29851 | 0 | 16 |
| 67 | 14.60308 | 4.46318 | 0.00746 | 0.01493 | 0.04664 | 0.10448 | 0.17164 | 0 | 8 |
| 73 | 10.54751 | 3.48978 | 0.00746 | 0.02985 | 0.15672 | 0.74627 | 0.99627 | 0 | 2 |
| 3115400 LITTLE MUSKINGUM RIVER AT BLOOMFIELD, OHIO | | | | | | | | | |
| 63 | 10.17976 | 3.69008 | 0.01429 | 0.02429 | 0.07143 | 0.22857 | 0.34762 | 0 | 0 |
| 67 | 37.86417 | 7.34758 | 0.00143 | 0.00219 | 0.01821 | 0.07143 | 0.13095 | 0 | 3 |
| 73 | 10.63248 | 3.96765 | 0.01619 | 0.03357 | 0.11548 | 0.47619 | 0.81190 | 0 | 0 |

TABLE 5-17. FLOW-RATIO STATISTICS, OHIO RIVER DRAINAGE BETWEEN EAST LIVERPOOL AND MARIETTA

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3110000 YELLOW CREEK NEAR HAMMONDSVILLE, OHIO, | | | | | | | | | | | | | | |
| 63 | 307000. | 303000. | 267000. | 58. | 57. | 50. | 6.45 | 6.38 | 5.61 | 11.17 | 2.71 | 3 | 90 | 1 |
| 67 | 387000. | 379000. | 363000. | 59. | 58. | 56. | 8.14 | 7.97 | 7.64 | 13.69 | 2.71 | 3 | 90 | 1 |
| 73 | 613000. | 584000. | 533000. | 67. | 64. | 58. | 12.89 | 12.28 | 11.21 | 19.33 | 2.71 | 3 | 90 | 1 |
| 3111500 SHORT CREEK NEAR DILLONVALE, OHIO | | | | | | | | | | | | | | |
| 63 | 361000. | 366000. | 340000. | 61. | 62. | 58. | 7.59 | 7.70 | 7.15 | 12.43 | 2.62 | 3 | 90 | 1 |
| 67 | 411000. | 416000. | 412000. | 66. | 67. | 66. | 8.65 | 8.74 | 8.66 | 13.15 | 2.62 | 3 | 90 | 1 |
| 73 | 582000. | 565000. | 521000. | 78. | 76. | 70. | 12.24 | 11.88 | 10.95 | 15.69 | 2.62 | 3 | 90 | 1 |
| 3114000 CAPTINA CREEK AT ARMSTRONG MILLS, OHIO | | | | | | | | | | | | | | |
| 63 | 284000. | 300000. | 253000. | 43. | 46. | 39. | 5.97 | 6.31 | 5.32 | 13.77 | 2.66 | 3 | 90 | 1 |
| 67 | 349000. | 356000. | 339000. | 49. | 50. | 48. | 7.35 | 7.49 | 7.14 | 14.98 | 2.66 | 3 | 90 | 1 |
| 73 | 557000. | 543000. | 516000. | 60. | 58. | 55. | 11.71 | 11.42 | 10.84 | 19.60 | 2.66 | 3 | 90 | 1 |
| 3115400 LITTLE MUSKINGUM RIVER AT BLOOMFIELD, OHIO | | | | | | | | | | | | | | |
| 63 | 303000. | 311000. | 266000. | 37. | 38. | 33. | 6.37 | 6.54 | 5.60 | 17.20 | 2.91 | 3 | 90 | 1 |
| 67 | 327000. | 341000. | 323000. | 46. | 48. | 46. | 6.87 | 7.17 | 6.80 | 14.87 | 2.91 | 3 | 90 | 1 |
| 73 | 503000. | 487000. | 446000. | 53. | 51. | 47. | 10.58 | 10.24 | 9.39 | 19.98 | 2.91 | 3 | 90 | 1 |

TABLE 5-18. RECHARGE STATISTICS, OHIO RIVER DRAINAGE BETWEEN EAST LIVERPOOL AND MARIETTA

EAST LIVERPOOL-MARRIETTA BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 3110000 YELLOW CREEK NEAR HAMMONDSVILLE, OHIO, | | | | | | | | | | | | |
| FX | 25000. | 87000. | 191000. | 84000. | 327000. | 1301000. | 980000. | 1390000. | 153000. | 50000. | 26000. | 14000. |
| SL | 25000. | 83000. | 219000. | 81000. | 340000. | 1206000. | 981000. | 1362000. | 152000. | 50000. | 24000. | 14000. |
| LM | 22000. | 76000. | 265000. | 84000. | 263000. | 1112000. | 911000. | 1368000. | 158000. | 48000. | 20000. | 12000. |
| 73 | | | | | | | | | | | | |
| FX | 89000. | 512000. | 1069000. | 635000. | 833000. | 1257000. | 1111000. | 1105000. | 528000. | 106000. | 83000. | 42000. |
| SL | 93000. | 536000. | 984000. | 600000. | 831000. | 1093000. | 1093000. | 1055000. | 514000. | 102000. | 88000. | 43000. |
| LM | 93000. | 506000. | 898000. | 573000. | 708000. | 891000. | 1080000. | 933000. | 506000. | 104000. | 81000. | 42000. |
| 67 3111500 SHORT CREEK NEAR DILLONVALE, OHIO | | | | | | | | | | | | |
| FX | 105000. | 147000. | 189000. | 96000. | 234000. | 941000. | 975000. | 1319000. | 414000. | 232000. | 165000. | 106000. |
| SL | 101000. | 151000. | 210000. | 92000. | 254000. | 969000. | 974000. | 1309000. | 411000. | 230000. | 162000. | 111000. |
| LM | 101000. | 136000. | 248000. | 94000. | 227000. | 918000. | 951000. | 1333000. | 416000. | 235000. | 158000. | 105000. |
| 73 | | | | | | | | | | | | |
| FX | 155000. | 307000. | 621000. | 515000. | 721000. | 1069000. | 1083000. | 1298000. | 661000. | 286000. | 186000. | 90000. |
| SL | 161000. | 318000. | 635000. | 498000. | 713000. | 990000. | 1048000. | 1205000. | 660000. | 286000. | 187000. | 90000. |
| LM | 161000. | 308000. | 585000. | 489000. | 712000. | 841000. | 981000. | 1044000. | 568000. | 296000. | 186000. | 93000. |
| 63 3115400 LITTLE MUSKINGUM RIVER AT BLOOMFIELD, OHIO | | | | | | | | | | | | |
| FX | 17000. | 183000. | 403000. | 311000. | 518000. | 1238000. | 417000. | 200000. | 268000. | 19000. | 61000. | 12000. |
| SL | 14000. | 165000. | 290000. | 339000. | 473000. | 1457000. | 402000. | 204000. | 292000. | 20000. | 68000. | 12000. |
| LM | 14000. | 108000. | 203000. | 293000. | 482000. | 1087000. | 432000. | 199000. | 311000. | 18000. | 58000. | 9005. |
| 67 | | | | | | | | | | | | |
| FX | 1053. | 58000. | 250000. | 83000. | 398000. | 1497000. | 560000. | 973000. | 61000. | 15000. | 9694. | 1846. |
| SL | 1066. | 55000. | 334000. | 77000. | 415000. | 1525000. | 563000. | 1021000. | 57000. | 14000. | 10030. | 1641. |
| LM | 865. | 27000. | 405000. | 87000. | 342000. | 1457000. | 514000. | 916000. | 64000. | 8538. | 9083. | 1243. |
| 73 | | | | | | | | | | | | |
| FX | 47000. | 671000. | 1194000. | 609000. | 795000. | 657000. | 1266000. | 522000. | 159000. | 105000. | 27000. | 12000. |
| SL | 50000. | 565000. | 1168000. | 605000. | 831000. | 718000. | 1124000. | 534000. | 167000. | 100000. | 27000. | 10000. |
| LM | 36000. | 465000. | 1092000. | 560000. | 789000. | 573000. | 963000. | 605000. | 155000. | 112000. | 26000. | 10000. |

TABLE 5-19. MONTHLY RECHARGE RATES, OHIO RIVER DRAINAGE

mining has been a major activity throughout the area. Permeable alluvial deposits form the flood plain of Yellow Creek, but elsewhere the alluvium is generally so fine grained that it has little natural storage.

Some ground-water supplies are obtained from alluvium, but most is pumped from sandstone aquifers. Yields commonly range from 5 to 25 gpm, the rate depending largely on the thickness and permeability of the aquifer and the construction of the well.

The region has high relief. Stream gradients commonly range between 15 and 200 feet per mile. The regional slope is westward or southward toward the Ohio River.

Annual precipitation in this region during 1963, 1967 and 1973 ranged between 25 to 35, 35 to 40, and 35 to 45 inches, respectively.

The highest stream flows generally occur during the spring runoff and after intense rain storms. From fall to midwinter flows are low and many of the smaller streams are dry. In Yellow, Short and Captina Creeks and the Little Muskingum River, respectively, the 90 percent flow during 1967 was .035, .163, .015, and .002 cfs/sq. mi. (Table 5-17).

The separation of hydrographs for each of these streams indicates abnormally high effective ground-water recharge rates when compared to the 90 percent flow (Table 5-18 and 5-19). These rates, ranging between 300,000 and 400,000 gpd/sq. mi., are typical of basins that contain extensive deposits of permeable outwash. The reason for the high recharge rates is coal mining, particularly strip mining, because of the large water storage capacity of spoil material. Because of the effects on stream flow brought about by mining, regional recharge rates shown on Figure 5-9 were based largely on data from regions to the immediate west and from flow-duration curves. Throughout most of this large basin, regional rates probably range from 100,000 to 200,000 gpd/sq. mi. during a year of average precipitation, although where thick shallow sandstone layers occur it could be substantially higher. An investigation of the relation between streamflow and mining could be a fruitful area of research.

## Muskingum River Basin

The Muskingum River and its tributaries drain one-fifth of Ohio or 8,038 square miles (Fig. 5-10). The Muskingum originates at the confluence of the Tuscarawas (2590 sq. mi.) and Walhonding (2252 sq. mi.) Rivers and continues 112 miles to the Ohio River at Marietta. The basin lies entirely within the Appalachian Plateau. Other major tributaries that flow directly into the Muskingum River include Wills (853 sq. mi.) Wakatomika (234 sq. mi.) Moxohala (301 sq. mi.) and Salt (146 sq. mi.) Creeks and the Licking River (780 sq. mi.).

The average gradient of the Muskingum River is 1.3 feet per mile with lower gradients for major tributaries to the north (3.1 to 7 ft/mi.) and much higher gradients for tributaries to the south (8 to 130 ft/mi.).

Bedrock, of Mississippian, Pennsylvanian and Permian ages, consists of interbedded sandstones and shales with occasional thin limestones, coal seams, and clays. Some sandstones are sources of water but generally contribute very little to base flow.

Pleistocene age thick valley deposits of sand and gravel supply most of the base flow to streams in this basin. Melt water deposits, such as valley trains, kames and kame terraces also provide a significant amount of base flow. North of the glacial boundary thin till covers large areas.

Well yields vary from moderately high in the north and west to very low in the south and east. Yields in excess of 100 gpm have been developed in the sand and gravel deposits that fill valleys adjacent to perennial streams. Most of the major ground-water development has been in the numerous buried valleys and

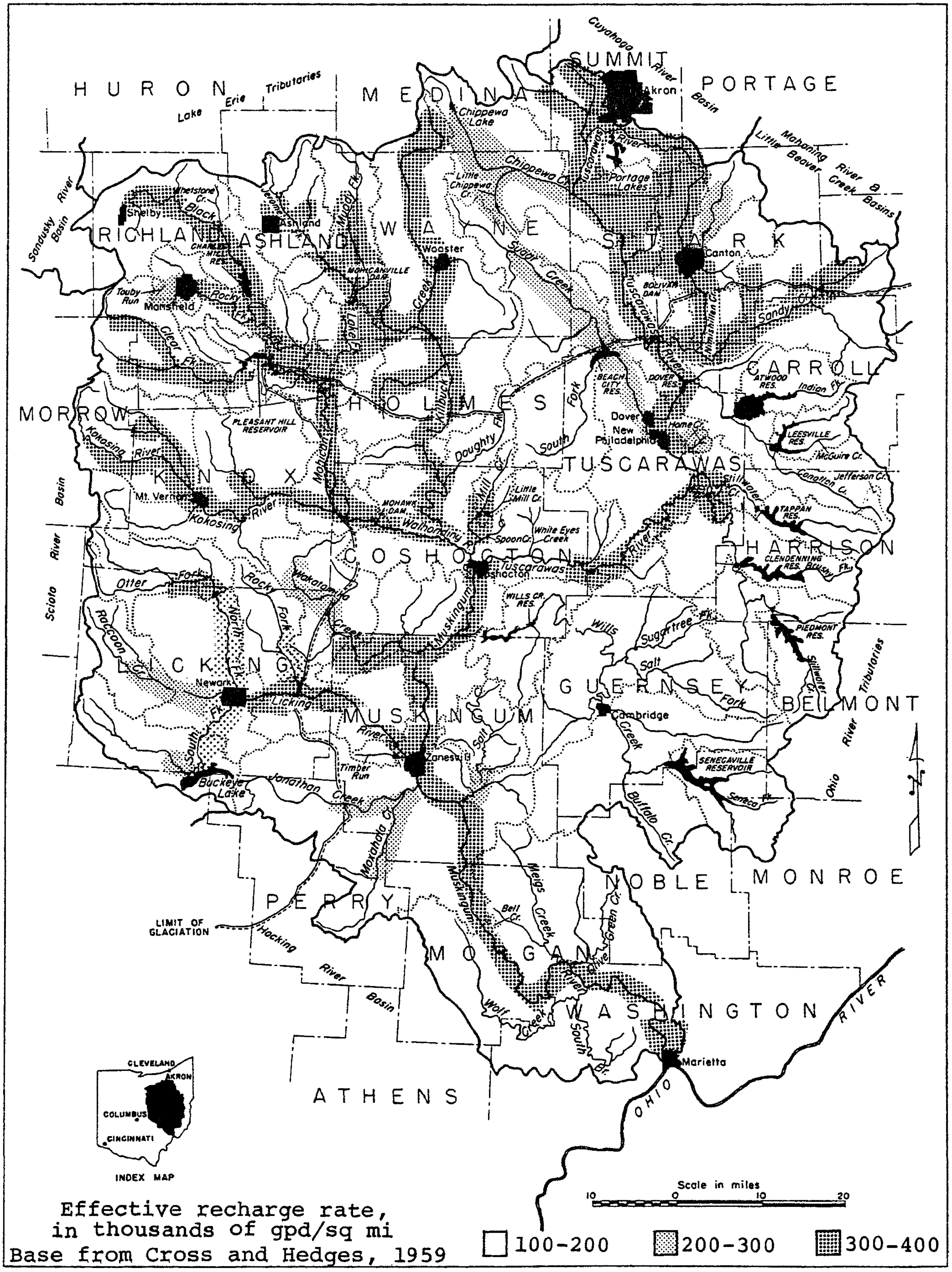



FIGURE 5-10. EFFECTIVE RECHARGE RATES IN THE MUSKINGUM RIVER BASIN

streamside aquifers in this basin. Thick, permeable sand and gravel deposits in buried valleys not under present day stream channels typically yield from 100 to 500 gpm. Much of the basin to the north and west also has good yields for domestic wells over most of the area which are obtained from interbedded sands and till or from underlying sandstone aquifers. Yields are often 5 to 25 gpm. Almost all the extreme upper part of the basin (Tuscarawas, Sandy Creek, Killbuck Creek, Mohican River) and western part of the basin (Mohican, Kokosing, Licking Rivers) can be expected to supply adequate water for domestic uses.

In the unglaciated Permian and Pennsylvanian areas of the basin, only the outwash provides adequate supplies of water. Yields less than 5 gpm are common from alternating layers of sandstone and shale. Similar yields also can be expected in the sandstone, shale, clay, coal, and limestone cyclothems.

Precipitation for the water years 1963, 1967, and 1973 range from 25 to 35, 30 to 40, 35 to 45 inches, respectively. Precipitation patterns for 1963 show a trend of lower precipitation in the north and higher in the south. The year 1967 had a pattern similar to the 1931-60 pattern with relatively even precipitation over the basin except for a high near Coshocton and a low through around Zanesville. Marietta was around 35 inches for both 1963 and 1967, as compared to a long term average of 39 to 40 inches. In 1973 a pattern of increasing precipitation from north to south developed but it was quite unlike the long term average pattern.

Highest flows occur during the spring and the lowest occur during late summer and fall. Many of the small streams in the unglaciated plateau go completely dry during this period. Anomalously high flows occurred in water year 1973 over much of the western part of the basin during November and December. These high flows substantially increased the effective recharge rate for that year. Considering the season, it is questionable how much infiltration actually occurred.

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| | 3116000 TUSCARAWAS RIVER AT CLINTON, OHIO | | | | | | | | |
| 63 | 1.84218 | 1.14953 | 0.24713 | 0.27011 | 0.32184 | 0.33908 | 0.35057 | 0 | 0 |
| 67 | 2.42936 | 1.58114 | 0.31034 | 0.32184 | 0.35057 | 0.39080 | 0.43103 | 0 | 0 |
| 73 | 2.80737 | 1.71315 | 0.29310 | 0.33908 | 0.55172 | 0.79885 | 0.91092 | 0 | 1 |
| | 3116200 CHIPPEWA CREEK AT EASTON, OHIO | | | | | | | | |
| 63 | 4.53557 | 2.00000 | 0.04247 | 0.04795 | 0.06507 | 0.10959 | 0.13699 | 0 | 0 |
| 67 | 6.12143 | 3.05400 | 0.05753 | 0.06096 | 0.08904 | 0.15068 | 0.19863 | 0 | 0 |
| 73 | 5.68833 | 2.34579 | 0.06575 | 0.09589 | 0.31336 | 0.64384 | 0.82534 | 0 | 0 |
| | 3117000 TUSCARAWAS RIVER AT MASSILON, OHIO | | | | | | | | |
| 63 | 2.45207 | 1.33907 | 0.13707 | 0.15251 | 0.19595 | 0.21815 | 0.23359 | 0 | 0 |
| 67 | 3.42903 | 2.03572 | 0.15830 | 0.17568 | 0.21091 | 0.27220 | 0.31757 | 0 | 0 |
| 73 | 3.00235 | 1.82785 | 0.21429 | 0.27413 | 0.47973 | 0.72780 | 0.89479 | 0 | 0 |
| | 3117500 SANDY CREEK AT WAYNESBURG, OHIO | | | | | | | | |
| 63 | 4.12310 | 1.91833 | 0.07115 | 0.07905 | 0.12352 | 0.17391 | 0.23715 | 0 | 0 |
| 67 | 5.72371 | 3.01766 | 0.07905 | 0.09091 | 0.15810 | 0.26877 | 0.34980 | 0 | 0 |
| 73 | 3.52983 | 2.19174 | 0.20949 | 0.24506 | 0.42292 | 1.03557 | 1.27273 | 0 | 0 |
| | 3118000 MIDDLE BRANCH NIMISHILLEN CREEK AT CANTON, OHIO | | | | | | | | |
| 63 | 7.13506 | 2.38352 | 0.00928 | 0.01276 | 0.04002 | 0.06961 | 0.09049 | 0 | 0 |
| 67 | 5.51513 | 3.11805 | 0.04176 | 0.05568 | 0.08353 | 0.15313 | 0.25522 | 0 | 0 |
| 73 | 2.84103 | 1.84391 | 0.23202 | 0.32483 | 0.46404 | 0.78886 | 0.92807 | 0 | 0 |

TABLE 5-20. FLOW-RATIO STATISTICS FOR THE MUSKINGUM RIVER BASIN

TABLE 5-20 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3118500 NIMISHILLEN CREEK AT NORTH INDUSTRY, OHIO | | | | | | | | | |
| 63 | 1.84575 | 1.24653 | 0.32000 | 0.33714 | 0.37143 | 0.39429 | 0.41143 | 0 | 0 |
| 67 | 2.28798 | 1.57817 | 0.35429 | 0.37714 | 0.45714 | 0.53714 | 0.62571 | 0 | 0 |
| 73 | 2.11801 | 1.49039 | 0.55429 | 0.61143 | 0.82000 | 1.12000 | 1.30857 | 0 | 0 |
| 3120500 MCGUIRE CREEK BELOW LEESVILLE DAM, NEAR LEESVILLE, OHIO | | | | | | | | | |
| 63 | 8.16496 | 3.21665 | 0.03727 | 0.03727 | 0.08954 | 0.19048 | 0.24845 | 0 | 0 |
| 67 | 9.84251 | 6.59768 | 0.03313 | 0.03313 | 0.03520 | 0.06004 | 0.09110 | 0 | 0 |
| 73 | 7.93844 | 4.08075 | 0.03520 | 0.05487 | 0.12215 | 0.28986 | 0.86957 | 0 | 0 |
| 3121500 INDIAN FORK BELOW ATWOOD DAM, NEAR NEW CUMBERLAND, OHIO | | | | | | | | | |
| 63 | 7.74596 | 4.86973 | 0.02714 | 0.03000 | 0.03750 | 0.13143 | 0.22857 | 0 | 0 |
| 67 | 10.83974 | 5.98074 | 0.02857 | 0.03143 | 0.03714 | 0.05429 | 0.06357 | 0 | 0 |
| 73 | 5.12713 | 2.99652 | 0.10000 | 0.11929 | 0.17143 | 0.58571 | 1.02857 | 0 | 0 |
| 3122500 TUSCARAWAS RIVER BELOW DOVER DAM, NEAR DOVER, OHIO | | | | | | | | | |
| 63 | 2.80509 | 1.54340 | 0.15658 | 0.17865 | 0.23843 | 0.29324 | 0.34235 | 0 | 0 |
| 67 | 3.31566 | 2.09165 | 0.20071 | 0.22206 | 0.27046 | 0.33523 | 0.41352 | 0 | 0 |
| 73 | 2.71458 | 1.97333 | 0.32028 | 0.35979 | 0.50036 | 0.98221 | 1.20285 | 0 | 0 |
| 3123000 SUGAR CREEK ABOVE BEACH CITY DAM, AT BEACH CITY, OHIO | | | | | | | | | |
| 63 | 5.21339 | 2.00000 | 0.03000 | 0.03656 | 0.06875 | 0.10000 | 0.12500 | 0 | 0 |
| 67 | 5.94138 | 3.06365 | 0.04750 | 0.06250 | 0.08906 | 0.13125 | 0.20625 | 0 | 0 |
| 73 | 3.95601 | 2.03502 | 0.15000 | 0.18750 | 0.43125 | 0.72500 | 0.95000 | 0 | 0 |

TABLE 5-20 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3124000 SUGAR CREEK BELOW BEACH CITY DAM, NEAR BEACH CITY, OHIO | | | | | | | | | |
| 63 | 5.77762 | 2.36198 | 0.02033 | 0.03500 | 0.06333 | 0.11667 | 0.14667 | 0 | 0 |
| 67 | 7.23772 | 3.17251 | 0.03333 | 0.04333 | 0.09000 | 0.14000 | 0.19333 | 0 | 0 |
| 73 | 4.28999 | 2.37138 | 0.11333 | 0.16500 | 0.33417 | 0.75667 | 0.99667 | 0 | 0 |
| 3124500 SUGAR CREEK AT STRASBURG, OHIO | | | | | | | | | |
| 63 | 6.01981 | 2.27185 | 0.00643 | 0.03376 | 0.07476 | 0.12862 | 0.15434 | 0 | 2 |
| 67 | 7.96607 | 2.94575 | 0.01640 | 0.03859 | 0.09968 | 0.16077 | 0.21061 | 0 | 0 |
| 73 | 4.17000 | 2.33567 | 0.12540 | 0.17363 | 0.36013 | 0.80064 | 1.08039 | 0 | 0 |
| 3125000 HOME CREEK NEAR NEW PHILADELPHIA, OHIO | | | | | | | | | |
| 63 | 32.59599 | 2.59808 | 0.0 | 0.00100 | 0.06250 | 0.12500 | 0.12500 | 0 | 73 |
| 67 | 38.72983 | 4.76970 | 0.0 | 0.00100 | 0.02500 | 0.06250 | 0.10000 | 0 | 54 |
| 73 | 8.80341 | 3.43996 | 0.01220 | 0.02439 | 0.09146 | 0.40854 | 0.67073 | 0 | 1 |
| 3126000 STILLWATER CREEK AT PIEDMONT, OHIO | | | | | | | | | |
| 63 | 6.42877 | 2.71723 | 0.01803 | 0.06475 | 0.12295 | 0.27869 | 0.40164 | 0 | 0 |
| 67 | 7.15943 | 3.63089 | 0.05820 | 0.06844 | 0.12295 | 0.17213 | 0.24590 | 0 | 0 |
| 73 | 4.69042 | 2.44233 | 0.05328 | 0.13115 | 0.40984 | 0.69672 | 1.06147 | 0 | 0 |
| 3127000 STILLWATER CREEK AT TIPPECANOE, OHIO | | | | | | | | | |
| 63 | 7.49252 | 2.79990 | 0.02943 | 0.05142 | 0.12145 | 0.27660 | 0.35461 | 0 | 0 |
| 67 | 7.43303 | 3.55050 | 0.05319 | 0.06383 | 0.11702 | 0.20567 | 0.30142 | 0 | 0 |
| 73 | 6.43680 | 2.97439 | 0.04255 | 0.06560 | 0.24911 | 0.63830 | 1.20567 | 0 | 0 |

TABLE 5-20 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| | 3127500 STILLWATER CREEK AT UHRICHSVILLE, OHIO | | | | | | | | |
| 63 | 6.58856 | 2.29848 | 0.02725 | 0.05995 | 0.14441 | 0.26975 | 0.35422 | 0 | 0 |
| 67 | 8.17492 | 3.64616 | 0.04632 | 0.05586 | 0.12262 | 0.20708 | 0.29700 | 0 | 0 |
| 73 | 5.74184 | 3.07197 | 0.00872 | 0.08719 | 0.25409 | 0.78747 | 1.44959 | 0 | 1 |
| | 3128500 LITTLE STILLWATER CREEK BELOW TAPPAN DAM, AT TAPPAN, O. | | | | | | | | |
| 63 | 8.24345 | 2.93520 | 0.03094 | 0.03094 | 0.09142 | 0.18284 | 0.30942 | 0 | 0 |
| 67 | 11.66563 | 6.08581 | 0.02813 | 0.03235 | 0.03797 | 0.09142 | 0.13361 | 0 | 0 |
| 73 | 13.75000 | 8.03637 | 0.01828 | 0.02250 | 0.03375 | 0.08720 | 0.13783 | 0 | 0 |
| | 3129000 TUSCARAWAS RIVER AT NEWCOMERSTOWN, OHIO | | | | | | | | |
| 63 | 3.19765 | 1.64833 | 0.12330 | 0.16441 | 0.21784 | 0.26716 | 0.32881 | 0 | 0 |
| 67 | 4.05197 | 2.39159 | 0.14204 | 0.15944 | 0.21613 | 0.28817 | 0.36021 | 0 | 0 |
| 73 | 3.04238 | 2.04939 | 0.21736 | 0.28612 | 0.47073 | 0.93737 | 1.30986 | 0 | 0 |
| | 3130000 BLACK FORK BELOW CHARLES DAM, NEAR MIFFLIN, OHIO | | | | | | | | |
| 63 | 3.82426 | 2.39270 | 0.06912 | 0.07373 | 0.09217 | 0.16129 | 0.19355 | 0 | 0 |
| 67 | 6.29058 | 2.85163 | 0.05530 | 0.06452 | 0.14862 | 0.29032 | 0.47926 | 0 | 0 |
| 73 | 3.96194 | 1.86721 | 0.13825 | 0.22811 | 0.68203 | 1.03226 | 1.35434 | 0 | 0 |
| | 3130500 TOUBY RUN AT MANSFIELD, OHIO | | | | | | | | |
| 63 | 3.16228 | 1.63554 | 0.11029 | 0.14706 | 0.18382 | 0.23897 | 0.25735 | 0 | 0 |
| 67 | 6.17721 | 2.76172 | 0.07037 | 0.07037 | 0.10926 | 0.18519 | 0.25926 | 0 | 0 |
| 73 | 4.21464 | 2.18327 | 0.13971 | 0.13971 | 0.27574 | 0.44118 | 0.58824 | 0 | 0 |

TABLE 5-20 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| | 3131500 BLACK FORK AT LOUDONVILLE, OHIO | | | | | | | | |
| 63 | 2.65805 | 1.55456 | 0.12911 | 0.19771 | 0.24928 | 0.32951 | 0.40544 | 0 | 0 |
| 67 | 3,93036 | 2.13196 | 0.17765 | 0.19198 | 0.30086 | 0.40115 | 0.58453 | 0 | 0 |
| 73 | 2.63017 | 1.60394 | 0.32092 | 0.41834 | 0.93696 | 1.23782 | 1.47564 | 0 | 0 |
| | 3132000 CLEAR FORK AT BUTLER, OHIO | | | | | | | | |
| 63 | 2.60608 | 1.49702 | 0.16176 | 0.17647 | 0.20588 | 0.23529 | 0.26471 | 0 | 0 |
| 67 | 4.06202 | 2.22907 | 0.16176 | 0.17647 | 0.23529 | 0.36765 | 0.46324 | 0 | 0 |
| 73 | 3.00574 | 1.73934 | 0.25735 | 0.31985 | 0.58088 | 0.84559 | 1.05882 | 0 | 0 |
| | 3133500 CLEAR FORK BELOW PLEASANT HILL DAM, NEAR PERRYSVILLE,O. | | | | | | | | |
| 63 | 3.07318 | 1.68034 | 0.11616 | 0.13636 | 0.17172 | 0.22727 | 0.28283 | 0 | 0 |
| 67 | 4.14144 | 2.27261 | 0.14141 | 0.16667 | 0.22222 | 0.40404 | 0.49242 | 0 | 0 |
| 73 | 3.42377 | 1.84136 | 0.19192 | 0.22727 | 0.64646 | 0.93434 | 1.17172 | 0 | 0 |
| | 3135000 LAKE FORK BELOW MOHICANVILLE DAM, NEAR MOHICANVILLE, O. | | | | | | | | |
| 63 | 5.94673 | 1.98348 | 0.03321 | 0.04059 | 0.07011 | 0.09594 | 0.11808 | 0 | 0 |
| 67 | 7.03118 | 3.44674 | 0.05166 | 0.05904 | 0.09225 | 0.16974 | 0.23801 | 0 | 0 |
| 73 | 5.14328 | 2.10056 | 0.10701 | 0.13838 | 0.44742 | 0.68266 | 0.88376 | 0 | 0 |
| | 3136000 MOHICAN RIVER AT GREER, OHIO | | | | | | | | |
| 63 | 3.50784 | 1.59915 | 0.13924 | 0.14873 | 0.18645 | 0.24051 | 0.27743 | 0 | 0 |
| 67 | 4.07814 | 2.25979 | 0.13819 | 0.14873 | 0.22257 | 0.31646 | 0.45042 | 0 | 0 |
| 73 | 3.15409 | 1.60656 | 0.23734 | 0.30591 | 0.83782 | 1.10759 | 1.29219 | 0 | 0 |

TABLE 5-20 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| | | 3136500 KOKOSING RIVER AT MOUNT VERNON, OHIO | | | | | | | |
| 63 | 3.01954 | 1.56428 | 0.09406 | 0.12624 | 0.16337 | 0.20297 | 0.22772 | 0 | 0 |
| 67 | 4.75511 | 2.44019 | 0.12376 | 0.13366 | 0.21782 | 0.35149 | 0.47525 | 0 | 0 |
| 73 | 2.90727 | 1.61310 | 0.24257 | 0.38861 | 0.70916 | 0.98020 | 1.20297 | 0 | 0 |
| | | 3137000 KOKOSING RIVER AT MILLWOOD, OHIO | | | | | | | |
| 63 | 3.39853 | 1.66141 | 0.08791 | 0.10989 | 0.16044 | 0.21978 | 0.25055 | 0 | 0 |
| 67 | 4.20372 | 2.38954 | 0.15165 | 0.16044 | 0.21593 | 0.32088 | 0.46044 | 0 | 0 |
| 73 | 3.04964 | 1.69306 | 0.24615 | 0.37692 | 0.70769 | 1.00440 | 1.21868 | 0 | 0 |
| | | 3138500 WALHONDING RIVER BELOW MOHAWK DAM, AT NELLIE, OHIO | | | | | | | |
| 63 | 3.14732 | 1.58813 | 0.12093 | 0.14086 | 0.20233 | 0.26711 | 0.30498 | 0 | 0 |
| 67 | 4.18269 | 2.20921 | 0.13688 | 0.16312 | 0.23654 | 0.35415 | 0.47442 | 0 | 0 |
| 73 | 3.01583 | 1.61979 | 0.23654 | 0.34884 | 0.81229 | 1.08970 | 1.30897 | 0 | 0 |
| | | 3139000 KILLBUCK CREEK AT KILLBUCK OHIO, | | | | | | | |
| 63 | 4.05642 | 1.87083 | 0.06961 | 0.07143 | 0.10823 | 0.13853 | 0.17316 | 0 | 0 |
| 67 | 5.04425 | 2.76403 | 0.09307 | 0.09740 | 0.14123 | 0.23160 | 0.29870 | 0 | 0 |
| 73 | 3.55549 | 1.92380 | 0.18831 | 0.22944 | 0.58279 | 0.91991 | 1.18723 | 0 | 0 |
| | | 3140000 MILL CREEK NEAR COSHOCTON, OHIO | | | | | | | |
| 63 | 9.79796 | 2.85044 | 0.00368 | 0.01838 | 0.05882 | 0.16912 | 0.22059 | 0 | 0 |
| 67 | 10.68370 | 3.93303 | 0.01434 | 0.01820 | 0.05882 | 0.11029 | 0.16544 | 0 | 0 |
| 73 | 5.32291 | 2.92007 | 0.06985 | 0.09926 | 0.20588 | 0.73529 | 0.95588 | 0 | 0 |

TABLE 5-20 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| | 3140500 MUSKINGUM RIVER NEAR COSHOCTON, OHIO | | | | | | | | |
| 63 | 3.55238 | 1.67332 | 0.11155 | 0.14653 | 0.21609 | 0.26960 | 0.30871 | 0 | 0 |
| 67 | 4.19504 | 2.45814 | 0.12883 | 0.14910 | 0.21815 | 0.32929 | 0.40440 | 0 | 0 |
| 73 | 2.83622 | 1.83255 | 0.25108 | 0.32620 | 0.60609 | 1.07841 | 1.32949 | 0 | 0 |
| | 3141500 SENECA FORK BELOW SENECAVILLE DAM, NEAR SENECAVILLE, O. | | | | | | | | |
| 63 | 12.34909 | 6.77215 | 0.01864 | 0.02034 | 0.02458 | 0.09322 | 0.14407 | 0 | 0 |
| 67 | 11.75646 | 5.85170 | 0.02119 | 0.02373 | 0.02797 | 0.03305 | 0.04661 | 0 | 0 |
| 73 | 14.86106 | 8.38082 | 0.01695 | 0.01992 | 0.03559 | 0.08220 | 0.55085 | 0 | 0 |
| | 3142000 WILLS CREEK AT CAMBRIDGE, OHIO | | | | | | | | |
| 63 | 10.62622 | 3.13008 | 0.00764 | 0.02956 | 0.09421 | 0.18473 | 0.28695 | 0 | 0 |
| 67 | 10.15784 | 4.11685 | 0.02069 | 0.02709 | 0.05973 | 0.12808 | 0.22167 | 0 | 0 |
| 73 | 6.81773 | 3.72909 | 0.04926 | 0.06650 | 0.15086 | 0.54680 | 1.06773 | 0 | 0 |
| | 3142200 SALT FORK NEAR CAMBRIDGE, OHIO | | | | | | | | |
| 63 | 14.61630 | 3.63945 | 0.00180 | 0.00989 | 0.05126 | 0.12590 | 0.21583 | 0 | 11 |
| 67 | 30.55051 | 5.78252 | 0.0 | 0.00324 | 0.02878 | 0.10432 | 0.15468 | 0 | 19 |
| | 3142295 SALT FORK BELOW SALT FORK DAM, NEAR CAMBRIDGE, OHIO | | | | | | | | |
| 73 | 8.15178 | 3.14960 | 0.0 | 0.03899 | 0.19654 | 0.86164 | 1.19497 | 0 | 21 |
| | 3143500 WILLS CREEK BELOW WILLS CREEK DAM, AT WILLS CREEK, OHIO | | | | | | | | |
| 63 | 8.70455 | 2.32089 | 0.03088 | 0.07720 | 0.15439 | 0.23634 | 0.30523 | 0 | 0 |
| 67 | 6.95222 | 3.22533 | 0.04038 | 0.05701 | 0.10837 | 0.15321 | 0.27078 | 0 | 0 |
| 73 | 6.18025 | 3.11703 | 0.04632 | 0.07898 | 0.20903 | 0.77553 | 1.24703 | 0 | 0 |

TABLE 5-20 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| | 3144000 WAKATOMIKA CREEK NEAR FRAZEYSBURG, OHIO | | | | | | | | |
| 63 | 5.71548 | 2.35281 | 0.03214 | 0.04286 | 0.10000 | 0.20714 | 0.25714 | 0 | 0 |
| 67 | 5.10628 | 2.94109 | 0.08571 | 0.09643 | 0.14286 | 0.25714 | 0.39286 | 0 | 0 |
| 73 | 5.20817 | 2.54630 | 0.08571 | 0.11429 | 0.27321 | 0.61429 | 0.81429 | 0 | 0 |
| | 3144500 MUSKINGUM RIVER AT DRESDEN, OHIO | | | | | | | | |
| 63 | 3.81748 | 1.77504 | 0.09845 | 0.13683 | 0.21859 | 0.27866 | 0.31286 | 0 | 0 |
| 67 | 4.44812 | 2.57812 | 0.12348 | 0.14801 | 0.20899 | 0.30202 | 0.40047 | 0 | 0 |
| 73 | 3.07722 | 1.93461 | 0.23361 | 0.29868 | 0.57400 | 1.04288 | 1.42333 | 0 | 0 |
| | 3145000 SOUTH FORK LICKING RIVER NEAR HEBRON, OHIO | | | | | | | | |
| 73 | 5.41197 | 2.84165 | 0.12030 | 0.14286 | 0.30075 | 0.43609 | 0.88722 | 0 | 0 |
| | 3146000 NORTH FORK LICKING RIVER AT UTICA, OHIO | | | | | | | | |
| 73 | 7.07107 | 2.15811 | 0.05517 | 0.08448 | 0.39009 | 0.62069 | 0.89655 | 0 | 0 |
| | 3146500 LICKING RIVER NEAR NEWARK, OHIO | | | | | | | | |
| 63 | 4.22370 | 2.17438 | 0.08380 | 0.09870 | 0.12663 | 0.22719 | 0.27933 | 0 | 0 |
| 67 | 4.49569 | 2.62705 | 0.11918 | 0.13222 | 0.16993 | 0.29423 | 0.44600 | 0 | 0 |
| 73 | 3.70451 | 1.96982 | 0.18622 | 0.26257 | 0.50512 | 0.76536 | 1.05680 | 0 | 0 |
| | 3147500 LICKING RIVER BELOW DILLON DAM, NEAR DILLON FALLS, OHIO | | | | | | | | |
| 63 | 4.77087 | 2.48250 | 0.08556 | 0.08957 | 0.11497 | 0.18850 | 0.28810 | 0 | 0 |
| 67 | 5.03322 | 2.48953 | 0.10512 | 0.12129 | 0.18959 | 0.31941 | 0.50606 | 0 | 0 |
| 73 | 4.35695 | 2.21521 | 0.17985 | 0.21698 | 0.50809 | 0.78437 | 1.04178 | 0 | 0 |

TABLE 5-20 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| | 3150000 MUSKINGUM RIVER AT MCCONNELSVILLE, OHIO | | | | | | | | |
| 63 | 4.08666 | 1.84417 | 0.08825 | 0.13150 | 0.20918 | 0.26947 | 0.32404 | 0 | 0 |
| 67 | 4.55055 | 2.67856 | 0.12611 | 0.14282 | 0.19671 | 0.33953 | 0.44934 | 0 | 0 |
| 73 | 3.19232 | 1.92191 | 0.21019 | 0.28227 | 0.57633 | 1.12234 | 1.40798 | 0 | 0 |
| | 3150250 MEIGS CREEK NEAR BEVERLY, OHIO | | | | | | | | |
| 73 | 6.94131 | 3.01082 | 0.05000 | 0.08088 | 0.22610 | 0.87500 | 1.10294 | 0 | 0 |

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3116000 TUSCARAWAS RIVER AT CLINTON, OHIO | | | | | | | | | | | | | | |
| 63 | 300000. | 298000. | 285000. | 81. | 80. | 76. | 6.31 | 6.26 | 6.00 | 7.84 | 2.81 | 2 | 12 | 1 |
| 67 | 362000. | 367000. | 351000. | 70. | 71. | 68. | 7.60 | 7.73 | 7.37 | 10.92 | 2.81 | 2 | 12 | 1 |
| 73 | 606000. | 588000. | 520000. | 73. | 71. | 63. | 12.73 | 12.37 | 10.92 | 17.38 | 2.81 | 2 | 12 | 1 |
| 3116200 CHIPPEWA CREEK AT EASTON, OHIO | | | | | | | | | | | | | | |
| 63 | 265000. | 239000. | 216000. | 71. | 64. | 58. | 5.57 | 5.02 | 4.54 | 7.84 | 2.71 | 2 | 12 | 1 |
| 67 | 274000. | 277000. | 255000. | 53. | 54. | 50. | 5.77 | 5.83 | 5.37 | 10.84 | 2.71 | 2 | 12 | 1 |
| 73 | 542000. | 535000. | 464000. | 61. | 60. | 52. | 11.39 | 11.24 | 9.76 | 18.61 | 2.71 | 2 | 12 | 1 |
| 3117000 TUSCARAWAS RIVER AT MASSILON, OHIO | | | | | | | | | | | | | | |
| 63 | 234000. | 238000. | 234000. | 66. | 67. | 66. | 4.93 | 5.01 | 4.92 | 7.45 | 3.49 | 2 | 21 | 1 |
| 67 | 288000. | 288000. | 254000. | 60. | 60. | 53. | 6.05 | 6.05 | 5.34 | 10.12 | 3.49 | 2 | 21 | 1 |
| 73 | 477000. | 492000. | 475000. | 61. | 63. | 61. | 10.03 | 10.34 | 9.99 | 16.32 | 3.49 | 2 | 21 | 1 |
| 3117500 SANDY CREEK AT WAYNESBURG, OHIO | | | | | | | | | | | | | | |
| 63 | 258000. | 251000. | 238000. | 57. | 56. | 53. | 5.43 | 5.29 | 5.02 | 9.49 | 3.02 | 2 | 90 | 1 |
| 67 | 416000. | 420000. | 378000. | 63. | 63. | 57. | 8.75 | 8.83 | 7.96 | 13.95 | 3.02 | 2 | 90 | 1 |
| 73 | 600000. | 610000. | 578000. | 63. | 64. | 60. | 12.61 | 12.82 | 12.15 | 20.14 | 3.02 | 2 | 90 | 1 |
| 3118000 MIDDLE BRANCH NIMISHILLEN CREEK AT CANTON, OHIO | | | | | | | | | | | | | | |
| 63 | 133000. | 123000. | 113000. | 54. | 50. | 45. | 2.81 | 2.60 | 2.38 | 5.25 | 2.12 | 2 | 21 | 1 |
| 67 | 252000. | 253000. | 236000. | 58. | 58. | 55. | 5.30 | 5.33 | 4.98 | 9.13 | 2.12 | 2 | 21 | 1 |
| 73 | 527000. | 525000. | 513000. | 64. | 64. | 62. | 11.08 | 11.03 | 10.79 | 17.26 | 2.12 | 2 | 21 | 1 |

TABLE 5-21. RECHARGE STATISTICS FOR THE MUSKINGUM RIVER BASIN

TABLE 5-21 CONTINUED

| YR | RECHARGE RATE, GPD/SQ.MI. FIXED | SLIDING | LOCMIN | GW, PERCENT FX | SL | LM | GW, IN INCHES FX | SL | LM | DIS IN | N DAYS | GEOLOGY REL | SUR | BRK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3118500 NIMISHILLEN CREEK AT NORTH INDUSTRY, OHIO | | | | | | | | | | | | | | |
| 63 | 315000. | 309000. | 292000. | 66. | 65. | 61. | 6.62 | 6.51 | 6.14 | 10.06 | 2.81 | 2 | 21 | 1 |
| 67 | 445000. | 450000. | 445000. | 70. | 71. | 70. | 9.37 | 9.47 | 9.37 | 13.36 | 2.81 | 2 | 21 | 1 |
| 73 | 708000. | 710000. | 702000. | 70. | 71. | 70. | 14.88 | 14.91 | 14.76 | 21.15 | 2.81 | 2 | 21 | 1 |
| 3120500 MCGUIRE CREEK BELOW LEESVILLE DAM, NEAR LEESVILLE, OH | | | | | | | | | | | | | | |
| 63 | 408000. | 411000. | 391000. | 73. | 74. | 70. | 8.58 | 8.65 | 8.21 | 11.72 | 2.17 | 3 | 90 | 1 |
| 67 | 452000. | 469000. | 438000. | 72. | 74. | 70. | 9.51 | 9.85 | 9.21 | 13.23 | 2.17 | 3 | 90 | 1 |
| 73 | 544000. | 550000. | 465000. | 70. | 71. | 60. | 11.44 | 11.57 | 9.77 | 16.39 | 2.17 | 3 | 90 | 1 |
| 3121500 INDIAN FORK BELOW ATWOOD DAM, NEAR NEW CUMBERLAND, OH | | | | | | | | | | | | | | |
| 63 | 333000. | 332000. | 286000. | 70. | 70. | 60. | 7.01 | 6.98 | 6.01 | 10.03 | 2.34 | 3 | 90 | 1 |
| 67 | 421000. | 410000. | 321000. | 66. | 64. | 50. | 8.85 | 8.63 | 6.75 | 13.42 | 2.34 | 3 | 90 | 1 |
| 73 | 507000. | 505000. | 447000. | 64. | 64. | 57. | 10.65 | 10.61 | 9.39 | 16.59 | 2.34 | 3 | 90 | 1 |
| 3122500 TUSCARAWAS RIVER BELOW DOVER DAM, NEAR DOVER, OHIO | | | | | | | | | | | | | | |
| 63 | 302000. | 304000. | 241000. | 65. | 65. | 52. | 6.36 | 6.40 | 6.40 | 9.80 | 4.26 | 3 | 90 | 1 |
| 67 | 355000. | 364000. | 314000. | 60. | 61. | 53. | 7.46 | 7.67 | 7.71 | 12.49 | 4.26 | 3 | 90 | 1 |
| 73 | 574000. | 599000. | 596000. | 65. | 68. | 67. | 12.06 | 12.60 | 12.75 | 18.57 | 4.26 | 3 | 90 | 1 |
| 3123000 SUGAR CREEK ABOVE BEACH CITY DAM, AT BEACH CITY, OHIO | | | | | | | | | | | | | | |
| 63 | 147000. | 143000. | 124000. | 49. | 47. | 41. | 3.10 | 3.01 | 2.63 | 6.39 | 2.76 | 3 | 90 | 1 |
| 67 | 273000. | 275000. | 242000. | 57. | 57. | 50. | 5.75 | 5.78 | 5.10 | 10.18 | 2.76 | 3 | 90 | 1 |
| 73 | 530000. | 531000. | 491000. | 59. | 60. | 55. | 11.14 | 11.15 | 10.33 | 18.74 | 2.76 | 3 | 90 | 1 |

TABLE 5-21 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3124000 SUGAR CREEK BELOW BEACH CITY DAM, NEAR BEACH CITY, OH | | | | | | | | | | | | | | |
| 63 | 248000. | 233000. | 171000. | 63. | 59. | 43. | 5.23 | 4.90 | 3.61 | 8.30 | 3.13 | 3 | 90 | 1 |
| 67 | 269000. | 279000. | 274000. | 55. | 57. | 56. | 5.67 | 5.88 | 5.77 | 10.35 | 3.13 | 3 | 90 | 1 |
| 73 | 512000. | 519000. | 500000. | 58. | 59. | 57. | 10.76 | 10.92 | 10.50 | 18.40 | 3.13 | 3 | 90 | 1 |
| 3124500 SUGAR CREEK AT STRASBURG, OHIO | | | | | | | | | | | | | | |
| 63 | 252000. | 237000. | 179000. | 63. | 59. | 45. | 5.31 | 4.99 | 3.78 | 8.48 | 3.15 | 3 | 90 | 1 |
| 67 | 273000. | 285000. | 281000. | 52. | 55. | 54. | 5.74 | 5.99 | 5.92 | 10.99 | 3.15 | 3 | 90 | 1 |
| 73 | 535000. | 540000. | 516000. | 60. | 60. | 58. | 11.24 | 11.35 | 10.84 | 18.85 | 3.15 | 3 | 90 | 1 |
| 3125000 HOME CREEK NEAR NEW PHILADELPHIA, OHIO | | | | | | | | | | | | | | |
| 63 | 175000. | 195000. | 179000. | 44. | 49. | 45. | 3.68 | 4.10 | 3.76 | 8.43 | 1.10 | 3 | 90 | 1 |
| 67 | 207000. | 205000. | 176000. | 62. | 62. | 53. | 4.36 | 4.33 | 3.71 | 6.98 | 1.10 | 3 | 90 | 1 |
| 73 | 349000. | 357000. | 305000. | 62. | 64. | 55. | 7.34 | 7.51 | 6.42 | 11.76 | 1.10 | 3 | 90 | 1 |
| 3126000 STILLWATER CREEK AT PIEDMONT, OHIO | | | | | | | | | | | | | | |
| 63 | 470000. | 458000. | 444000. | 74. | 72. | 70. | 9.87 | 9.62 | 9.34 | 13.40 | 2.61 | 3 | 90 | 1 |
| 67 | 493000. | 501000. | 430000. | 74. | 75. | 64. | 10.37 | 10.53 | 9.04 | 14.07 | 2.61 | 3 | 90 | 1 |
| 73 | 736000. | 742000. | 674000. | 82. | 83. | 75. | 15.47 | 15.59 | 14.17 | 18.90 | 2.61 | 3 | 90 | 1 |
| 3127000 STILLWATER CREEK AT TIPPECANOE, OHIO | | | | | | | | | | | | | | |
| 63 | 386000. | 388000. | 383000. | 62. | 63. | 62. | 8.13 | 8.17 | 8.06 | 13.05 | 3.09 | 3 | 90 | 1 |
| 67 | 450000. | 448000. | 404000. | 68. | 68. | 61. | 9.47 | 9.42 | 8.50 | 13.95 | 3.09 | 3 | 90 | 1 |
| 73 | 617000. | 623000. | 588000. | 72. | 73. | 69. | 12.98 | 13.10 | 12.36 | 18.01 | 3.09 | 3 | 90 | 1 |

TABLE 5-21 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3127500 STILLWATER CREEK AT UHRICHSVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 388000. | 401000. | 376000. | 60. | 62. | 58. | 8.17 | 8.44 | 7.91 | 13.58 | 3.26 | 3 | 90 | 1 |
| 67 | 478000. | 483000. | 453000. | 66. | 66. | 62. | 10.06 | 10.16 | 9.53 | 15.33 | 3.26 | 3 | 90 | 1 |
| 73 | 704000. | 707000. | 709000. | 76. | 77. | 77. | 14.80 | 14.87 | 14.90 | 19.36 | 3.26 | 3 | 90 | 1 |
| 3128500 LITTLE STILLWATER CREEK BELOW TAPPAN DAM, AT TAPPAN, | | | | | | | | | | | | | | |
| 63 | 346000. | 363000. | 261000. | 60. | 63. | 46. | 7.28 | 7.63 | 5.50 | 12.05 | 2.35 | 3 | 90 | 1 |
| 67 | 385000. | 402000. | 268000. | 54. | 57. | 38. | 8.10 | 8.45 | 5.64 | 14.87 | 2.35 | 3 | 90 | 1 |
| 73 | 355000. | 364000. | 257000. | 45. | 46. | 33. | 7.47 | 7.66 | 5.41 | 16.58 | 2.35 | 3 | 90 | 1 |
| 3129000 TUSCARAWAS RIVER AT NEWCOMERSTOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 331000. | 351000. | 298000. | 67. | 71. | 61. | 6.97 | 7.38 | 7.39 | 10.34 | 4.76 | 3 | 21 | 1 |
| 67 | 378000. | 390000. | 320000. | 64. | 66. | 54. | 7.94 | 8.20 | 8.23 | 12.39 | 4.76 | 3 | 21 | 1 |
| 73 | 603000. | 617000. | 586000. | 69. | 71. | 67. | 12.67 | 12.98 | 13.08 | 18.28 | 4.76 | 3 | 21 | 1 |
| 3130000 BLACK FORK BELOW CHARLES DAM, NEAR MIFFLIN, OHIO | | | | | | | | | | | | | | |
| 63 | 347000. | 335000. | 278000. | 76. | 73. | 61. | 7.29 | 7.04 | 5.86 | 9.65 | 2.93 | 2 | 21 | 2 |
| 67 | 450000. | 450000. | 336000. | 74. | 74. | 56. | 9.46 | 9.46 | 7.38 | 12.73 | 2.93 | 2 | 21 | 2 |
| 73 | 821000. | 812000. | 581000. | 77. | 77. | 55. | 17.25 | 17.06 | 12.22 | 22.27 | 2.93 | 2 | 21 | 2 |
| 3130500 TOUBY RUN AT MANSFIELD, OHIO | | | | | | | | | | | | | | |
| 63 | 236000. | 246000. | 226000. | 53. | 55. | 51. | 4.97 | 5.18 | 4.77 | 9.38 | 1.40 | 2 | 21 | 2 |
| 67 | 296000. | 298000. | 253000. | 43. | 44. | 37. | 6.23 | 6.27 | 5.32 | 14.41 | 1.40 | 2 | 21 | 2 |
| 73 | 396000. | 405000. | 356000. | 57. | 59. | 52. | 8.33 | 8.52 | 7.49 | 14.54 | 1.40 | 2 | 21 | 2 |

TABLE 5-21 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3131500 BLACK FORK AT LOUDONVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 381000. | 362000. | 365000. | 73. | 70. | 70. | 8.02 | 7.61 | 7.68 | 10.95 | 3.23 | 2 | 21 | 2 |
| 67 | 495000. | 473000. | 380000. | 74. | 71. | 57. | 10.42 | 9.94 | 7.99 | 13.99 | 3.23 | 2 | 21 | 2 |
| 73 | 832000. | 837000. | 738000. | 77. | 77. | 68. | 17.49 | 17.59 | 15.51 | 22.77 | 3.23 | 2 | 21 | 2 |
| 3132000 CLEAR FORK AT BUTLER, OHIO | | | | | | | | | | | | | | |
| 63 | 282000. | 284000. | 262000. | 59. | 59. | 55. | 5.93 | 5.97 | 5.51 | 10.06 | 2.67 | 2 | 21 | 2 |
| 67 | 415000. | 418000. | 407000. | 59. | 59. | 58. | 8.72 | 8.80 | 8.55 | 14.80 | 2.67 | 2 | 21 | 2 |
| 73 | 603000. | 597000. | 572000. | 65. | 65. | 62. | 12.67 | 12.55 | 12.02 | 19.38 | 2.67 | 2 | 21 | 2 |
| 3133500 CLEAR FORK BELOW PLEASANT HILL DAM, NEAR PERRYSVILLE, | | | | | | | | | | | | | | |
| 63 | 339000. | 343000. | 308000. | 77. | 78. | 70. | 7.13 | 7.22 | 6.47 | 9.21 | 2.88 | 2 | 21 | 2 |
| 67 | 464000. | 487000. | 433000. | 72. | 76. | 67. | 9.75 | 10.25 | 9.10 | 13.49 | 2.88 | 2 | 21 | 2 |
| 73 | 693000. | 703000. | 604000. | 76. | 77. | 66. | 14.56 | 14.78 | 12.70 | 19.28 | 2.88 | 2 | 21 | 2 |
| 3135000 LAKE FORK BELOW MOHICANVILLE DAM, NEAR MOHICANVILLE, | | | | | | | | | | | | | | |
| 63 | 295000. | 272000. | 242000. | 74. | 68. | 61. | 6.22 | 5.72 | 5.10 | 8.36 | 3.07 | 2 | 11 | 2 |
| 67 | 296000. | 291000. | 278000. | 56. | 55. | 52. | 6.23 | 6.13 | 5.84 | 11.22 | 3.07 | 2 | 11 | 2 |
| 73 | 518000. | 535000. | 488000. | 57. | 59. | 54. | 10.90 | 11.26 | 10.25 | 19.09 | 3.07 | 2 | 11 | 2 |
| 3136000 MOHICAN RIVER AT GREER, OHIO | | | | | | | | | | | | | | |
| 63 | 363000. | 336000. | 306000. | 77. | 72. | 65. | 7.63 | 7.08 | 6.44 | 9.86 | 3.94 | 2 | 90 | 2 |
| 67 | 409000. | 396000. | 336000. | 71. | 69. | 58. | 8.59 | 8.33 | 7.07 | 12.15 | 3.94 | 2 | 90 | 2 |
| 73 | 753000. | 755000. | 695000. | 75. | 75. | 69. | 15.83 | 15.87 | 14.60 | 21.02 | 3.94 | 2 | 90 | 2 |

TABLE 5-21 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3136500 KOKOSING RIVER AT MOUNT VERNON, OHIO | | | | | | | | | | | | | | |
| 63 | 264000. | 254000. | 230000. | 55. | 53. | 48. | 5.55 | 5.36 | 4.84 | 10.15 | 2.89 | 2 | 21 | 2 |
| 67 | 418000. | 425000. | 423000. | 56. | 57. | 57. | 8.79 | 8.94 | 8.89 | 15.59 | 2.89 | 2 | 21 | 2 |
| 73 | 655000. | 649000. | 612000. | 63. | 62. | 59. | 13.77 | 13.64 | 12.86 | 21.83 | 2.89 | 2 | 21 | 2 |
| 3137000 KOKOSING RIVER AT MILLWOOD, OHIO | | | | | | | | | | | | | | |
| 63 | 252000. | 242000. | 238000. | 50. | 48. | 47. | 5.31 | 5.09 | 5.02 | 10.62 | 3.40 | 2 | 21 | 2 |
| 67 | 396000. | 392000. | 374000. | 56. | 56. | 53. | 8.32 | 8.25 | 7.88 | 14.77 | 3.40 | 2 | 21 | 2 |
| 73 | 646000. | 637000. | 625000. | 59. | 58. | 57. | 13.58 | 13.40 | 13.13 | 23.09 | 3.40 | 2 | 21 | 2 |
| 3138500 WALHONDING RIVER BELOW MOHAWK DAM AT NELLIE, OHIO | | | | | | | | | | | | | | |
| 63 | 256000. | 289000. | 175000. | 51. | 58. | 36. | 5.40 | 6.07 | 6.08 | 10.49 | 4.32 | 3 | 21 | 2 |
| 67 | 376000. | 368000. | 346000. | 60. | 59. | 56. | 7.90 | 7.74 | 7.78 | 13.15 | 4.32 | 3 | 21 | 2 |
| 73 | 671000. | 689000. | 660000. | 66. | 67. | 65. | 14.10 | 14.47 | 14.69 | 21.46 | 4.32 | 3 | 21 | 2 |
| 3139000 KILLBUCK CREEK AT KILLBUCK OHIO, | | | | | | | | | | | | | | |
| 63 | 217000. | 231000. | 193000. | 62. | 66. | 55. | 4.57 | 4.85 | 4.06 | 7.41 | 3.41 | 3 | 21 | 2 |
| 67 | 344000. | 342000. | 304000. | 69. | 69. | 61. | 7.24 | 7.18 | 6.40 | 10.43 | 3.41 | 3 | 21 | 2 |
| 73 | 679000. | 682000. | 635000. | 72. | 73. | 68. | 14.28 | 14.34 | 13.34 | 19.74 | 3.41 | 3 | 21 | 2 |
| 3140000 MILL CREEK NEAR COSHOCTON, OHIO | | | | | | | | | | | | | | |
| 63 | 252000. | 295000. | 211000. | 42. | 49. | 35. | 5.31 | 6.21 | 4.43 | 12.57 | 1.94 | 3 | 21 | 2 |
| 67 | 320000. | 323000. | 278000. | 63. | 64. | 55. | 6.74 | 6.80 | 5.84 | 10.67 | 1.94 | 3 | 21 | 2 |
| 73 | 577000. | 594000. | 541000. | 67. | 69. | 63. | 12.13 | 12.49 | 11.38 | 18.10 | 1.94 | 3 | 21 | 2 |

TABLE 5-21 CONTINUED

| YR | RECHARGE RATE, GPD/SQ.MI. FIXED | SLIDING | LOCMIN | GW, PERCENT FX | SL | LM | GW, IN INCHES FX | SL | LM | DIS IN | N DAYS | GEOLOGY REL | SUR | BRK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3140500 MUSKINGUM RIVER NEAR COSHOCTON, OHIO | | | | | | | | | | | | | | |
| 63 | 324000. | 325000. | 265000. | 67. | 67. | 54. | 6.81 | 6.84 | 6.84 | 10.20 | 5.46 | 3 | 21 | 2 |
| 67 | 394000. | 375000. | 328000. | 68. | 65. | 57. | 8.30 | 7.90 | 7.93 | 12.21 | 5.46 | 3 | 21 | 2 |
| 73 | 650000. | 632000. | 592000. | 70. | 68. | 64. | 13.67 | 13.29 | 13.47 | 19.60 | 5.46 | 3 | 21 | 2 |
| 3141500 SENECA FORK BELOW SENECAVILLE DAM, NEAR SENECAVILLE, | | | | | | | | | | | | | | |
| 63 | 441000. | 443000. | 262000. | 66. | 66. | 39. | 9.28 | 9.33 | 5.51 | 14.15 | 2.60 | 3 | 90 | 2 |
| 67 | 357000. | 334000. | 238000. | 63. | 59. | 42. | 7.52 | 7.02 | 5.01 | 11.91 | 2.60 | 3 | 90 | 2 |
| 73 | 431000. | 442000. | 295000. | 49. | 51. | 34. | 9.06 | 9.29 | 6.21 | 18.32 | 2.60 | 3 | 90 | 2 |
| 3142000 WILLS CREEK AT CAMBRIDGE, OHIO | | | | | | | | | | | | | | |
| 63 | 355000. | 348000. | 271000. | 47. | 46. | 36. | 7.47 | 7.31 | 5.71 | 15.75 | 3.32 | 3 | 90 | 2 |
| 67 | 321000. | 305000. | 245000. | 57. | 54. | 43. | 6.75 | 6.42 | 5.15 | 11.86 | 3.32 | 3 | 90 | 2 |
| 73 | 516000. | 529000. | 511000. | 61. | 62. | 60. | 10.85 | 11.11 | 10.74 | 17.84 | 3.32 | 3 | 90 | 2 |
| 3142200 SALT FORK NEAR CAMBRIDGE, OHIO | | | | | | | | | | | | | | |
| 63 | 233000. | 258000. | 229000. | 36. | 39. | 35. | 4.90 | 5.43 | 4.81 | 13.80 | 2.23 | 3 | 90 | 2 |
| 67 | 296000. | 295000. | 258000. | 45. | 45. | 39. | 6.23 | 6.21 | 5.44 | 13.79 | 2.23 | 3 | 90 | 2 |
| 3142295 SALT FORK BELOW SALT FORK DAM, NEAR CAMBRIDGE, OHIO 7 | | | | | | | | | | | | | | |
| 73 | 677000. | 677000. | 633000. | 86. | 86. | 81. | 14.24 | 14.24 | 13.30 | 16.53 | 2.76 | 3 | 90 | 2 |
| 3143500 WILLS CREEK BELOW WILLS CREEK DAM, AT WILLS CREEK, OH | | | | | | | | | | | | | | |
| 63 | 494000. | 514000. | 355000. | 65. | 67. | 46. | 10.39 | 10.80 | 7.46 | 16.07 | 3.85 | 3 | 21 | 2 |
| 67 | 398000. | 376000. | 336000. | 65. | 61. | 55. | 8.37 | 7.91 | 7.07 | 12.94 | 3.85 | 3 | 21 | 2 |
| 73 | 642000. | 628000. | 601000. | 75. | 73. | 70. | 13.50 | 13.21 | 12.64 | 17.97 | 3.85 | 3 | 21 | 2 |

TABLE 5-21 CONTINUED

| YR | RECHARGE RATE, GPD/SQ.MI. FIXED | SLIDING | LOCMIN | GW, PERCENT FX | SL | LM | GW, IN INCHES FX | SL | LM | DIS IN | N DAYS | GEOLOGY REL | SUR | BRK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3144000 WAKATOMIKA CREEK NEAR FRAZEYSBURG, OHIO | | | | | | | | | | | | | | |
| 63 | 254000. | 262000. | 227000. | 45. | 46. | 40. | 5.35 | 5.52 | 4.78 | 11.90 | 2.69 | 3 | 90 | 2 |
| 67 | 381000. | 383000. | 340000. | 60. | 61. | 54. | 8.02 | 8.06 | 7.16 | 13.30 | 2.69 | 3 | 90 | 2 |
| 73 | 546000. | 545000. | 508000. | 65. | 65. | 61. | 11.48 | 11.47 | 10.69 | 17.57 | 2.69 | 3 | 90 | 2 |
| 3144500 MUSKINGUM RIVER AT DRESDEN, OHIO | | | | | | | | | | | | | | |
| 63 | 355000. | 359000. | 288000. | 66. | 67. | 53. | 7.46 | 7.56 | 7.57 | 11.35 | 5.70 | 3 | 21 | 2 |
| 67 | 413000. | 394000. | 357000. | 67. | 64. | 58. | 8.69 | 8.29 | 8.33 | 12.91 | 5.70 | 3 | 21 | 2 |
| 73 | 685000. | 671000. | 638000. | 72. | 71. | 67. | 14.39 | 14.10 | 14.25 | 19.88 | 5.70 | 3 | 21 | 2 |
| 3145000 SOUTH FORK LICKING RIVER NEAR HEBRON, OHIO | | | | | | | | | | | | | | |
| 73 | 581000. | 589000. | 523000. | 54. | 55. | 49. | 12.22 | 12.38 | 11.00 | 22.63 | 2.66 | 2 | 21 | 2 |
| 3146000 NORTH FORK LICKING RIVER AT UTICA, OHIO | | | | | | | | | | | | | | |
| 73 | 510000. | 503000. | 497000. | 42. | 41. | 41. | 10.71 | 10.57 | 10.46 | 25.49 | 2.59 | 2 | 21 | 2 |
| 3146500 LICKING RIVER NEAR NEWARK, OHIO | | | | | | | | | | | | | | |
| 63 | 296000. | 271000. | 225000. | 48. | 44. | 37. | 6.22 | 5.71 | 4.74 | 12.88 | 3.52 | 3 | 90 | 2 |
| 67 | 375000. | 360000. | 336000. | 54. | 52. | 48. | 7.88 | 7.57 | 7.07 | 14.60 | 3.52 | 3 | 90 | 2 |
| 73 | 549000. | 544000. | 536000. | 53. | 53. | 52. | 11.54 | 11.44 | 11.27 | 21.67 | 3.52 | 3 | 90 | 2 |
| 3147500 LICKING RIVER BELOW DILLON DAM, NEAR DILLON FALLS, OH | | | | | | | | | | | | | | |
| 63 | 294000. | 298000. | 236000. | 49. | 49. | 39. | 6.18 | 6.28 | 4.97 | 12.68 | 3.76 | 3 | 21 | 2 |
| 67 | 389000. | 353000. | 315000. | 56. | 51. | 45. | 8.18 | 7.43 | 6.63 | 14.69 | 3.75 | 3 | 21 | 2 |
| 73 | 578000. | 577000. | 535000. | 56. | 56. | 52. | 12.14 | 12.14 | 11.26 | 21.65 | 3.75 | 3 | 21 | 2 |

TABLE 5-21 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3150000 MUSKINGUM RIVER AT MCCONNELSVILLE, OHIO 1963 | | | | | | | | | | | | | | |
| 63 | 349000. | 330000. | 290000. | 67. | 64. | 56. | 7.35 | 6.95 | 6.96 | 10.92 | 5.94 | 3 | 90 | 1 |
| 67 | 417000. | 409000. | 368000. | 67. | 66. | 58. | 8.76 | 8.60 | 8.63 | 13.04 | 5.94 | 3 | 90 | 1 |
| 73 | 680000. | 675000. | 658000. | 72. | 72. | 70. | 14.30 | 14.19 | 14.33 | 19.80 | 5.94 | 3 | 90 | 1 |
| 3150250 MEIGS CREEK NEAR BEVERLY, OHIO | | | | | | | | | | | | | | |
| 73 | 589000. | 590000. | 524000. | 58. | 58. | 51. | 12.38 | 12.40 | 11.01 | 21.39 | 2.67 | 3 | 90 | 1 |

MUSKINGUM BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 3125000 HOME CREEK NEAR NEW PHILADELPHIA, OHIO | | | | | | | | | | | | |
| FX | 48000. | 125000. | 101000. | 119000. | 83000. | 861000. | 394000. | 170000. | 169000. | 19000. | 0. | 0. |
| SL | 48000. | 131000. | 102000. | 117000. | 90000. | 1072000. | 447000. | 171000. | 138000. | 11000. | 0. | 0. |
| LM | 48000. | 100000. | 96000. | 111000. | 82000. | 1139000. | 296000. | 173000. | 77000. | 3933. | 0. | 0. |
| 67 | | | | | | | | | | | | |
| FX | 0. | 47000. | 189000. | 63000. | 207000. | 695000. | 476000. | 726000. | 49000. | 13000. | 10000. | 2693. |
| SL | 0. | 43000. | 185000. | 67000. | 220000. | 730000. | 443000. | 696000. | 49000. | 13000. | 10000. | 3635. |
| LM | 0. | 35000. | 178000. | 63000. | 141000. | 569000. | 439000. | 607000. | 49000. | 11000. | 10000. | 542. |
| 73 | | | | | | | | | | | | |
| FX | 38000. | 424000. | 656000. | 374000. | 644000. | 812000. | 435000. | 554000. | 164000. | 39000. | 61000. | 7487. |
| SL | 40000. | 479000. | 657000. | 416000. | 660000. | 795000. | 450000. | 548000. | 162000. | 29000. | 63000. | 5911. |
| LM | 33000. | 378000. | 675000. | 318000. | 614000. | 596000. | 415000. | 439000. | 142000. | 19000. | 52000. | 3605. |
| 63 3130500 TOUBY RUN AT MANSFIELD, OHIO | | | | | | | | | | | | |
| FX | 135000. | 176000. | 191000. | 241000. | 206000. | 950000. | 407000. | 128000. | 95000. | 120000. | 98000. | 78000. |
| SL | 138000. | 189000. | 198000. | 242000. | 207000. | 1016000. | 432000. | 125000. | 98000. | 121000. | 108000. | 68000. |
| LM | 142000. | 169000. | 173000. | 257000. | 168000. | 886000. | 395000. | 122000. | 97000. | 122000. | 115000. | 63000. |
| 67 | | | | | | | | | | | | |
| FX | 108000. | 391000. | 613000. | 119000. | 288000. | 977000. | 448000. | 366000. | 70000. | 51000. | 43000. | 70000. |
| SL | 108000. | 367000. | 532000. | 115000. | 360000. | 972000. | 451000. | 438000. | 62000. | 49000. | 42000. | 80000. |
| LM | 109000. | 360000. | 445000. | 102000. | 172000. | 855000. | 459000. | 322000. | 53000. | 48000. | 42000. | 57000. |
| 73 | | | | | | | | | | | | |
| FX | 191000. | 573000. | 804000. | 319000. | 445000. | 991000. | 521000. | 292000. | 312000. | 143000. | 88000. | 77000. |
| SL | 193000. | 653000. | 827000. | 354000. | 394000. | 961000. | 563000. | 306000. | 306000. | 143000. | 86000. | 76000. |
| LM | 191000. | 518000. | 759000. | 302000. | 282000. | 905000. | 436000. | 290000. | 277000. | 139000. | 88000. | 73000. |
| 63 3136500 KOKOSING RIVER AT MOUNT VERNON, OHIO | | | | | | | | | | | | |
| FX | 97000. | 167000. | 153000. | 154000. | 146000. | 1411000. | 437000. | 197000. | 143000. | 97000. | 88000. | 55000. |
| SL | 98000. | 156000. | 148000. | 169000. | 148000. | 1315000. | 421000. | 198000. | 141000. | 98000. | 89000. | 54000. |
| LM | 105000. | 153000. | 140000. | 148000. | 149000. | 1056000. | 396000. | 204000. | 150000. | 99000. | 91000. | 54000. |
| 67 | | | | | | | | | | | | |
| FX | 84000. | 268000. | 611000. | 260000. | 417000. | 1247000. | 745000. | 824000. | 232000. | 129000. | 112000. | 74000. |
| SL | 83000. | 268000. | 714000. | 260000. | 430000. | 1230000. | 755000. | 804000. | 231000. | 129000. | 112000. | 76000. |
| LM | 82000. | 209000. | 852000. | 266000. | 353000. | 1174000. | 705000. | 868000. | 236000. | 130000. | 106000. | 68000. |
| 73 | | | | | | | | | | | | |
| FX | 439000. | 893000. | 1013000. | 607000. | 622000. | 1085000. | 1018000. | 725000. | 560000. | 410000. | 337000. | 147000. |
| SL | 453000. | 943000. | 999000. | 618000. | 612000. | 1024000. | 1006000. | 701000. | 555000. | 418000. | 309000. | 146000. |
| LM | 385000. | 931000. | 1025000. | 635000. | 561000. | 835000. | 976000. | 668000. | 560000. | 383000. | 239000. | 146000. |

TABLE 5-22. MONTHLY RECHARGE RATES FOR THE MUSKINGUM RIVER BASIN

The 90 percent flow in 1967 for Home Creek, Touby Run, and Kokosing River at Mount Vernon was .001, .070, and .134 cfs/sq. mi. respectively (Table 5-20).

Hydrograph separations are high in comparison with dry-weather flow indices for streams that are controlled. Most major streams in the basin are controlled by reservoirs and flood-control structures, especially in the eastern basin where only limited supplies of ground-water are available.

Along the upper reaches of many of the northern streams are thick, coarse-grained glacial deposits that sustain high dry-weather flows. Deep buried valleys also contribute large quantities of water to base flow. One notable example, with effective recharge rates ranging in a normal year from 300,000 to 400,000 gpd/ sq. mi., is the Licking River near Newark (Table 5-21). Tributaries flow through ground moraine and end moraine. Near Newark, North Fork and the Licking River flow through kame terraces, valley train, and outwash plains. A dramatic increase in dry-weather flow indices occurs at this point. Similar conditions affect the upper Tuscarawas tributaries that drain areas of kame moraine and thick outwash. These thick outwash-filled valleys produce large well yields and significantly increase base flow.

In contrast, the streams draining Pennsylvanian and Permian rocks have extremely low dry-weather flows. Recharge rates are much higher than would be expected, but for the most part, the gaging stations are located below control structures, causing the storage indicated by the separation to be unusually high. Also, extensive coal mining, both strip mining and underground mining, alters the natural storage in the basin. Strip mine spoil banks and siltation ponds greatly change the flow characteristics of streams in this bedrock area. Effective recharge rates in this part of the basin are probably less than 100,000 gpd/sq. mi., except for scattered outwash deposits. Because of these effects on stream characteristics, the effective recharge rates shown on Figure 5-10 were based largely on flow-duration curves and data collected prior to regulation. Considering the complicated stratigraphy of the eastern basin and the abundance of control structures it is extremely difficult to determine which effective recharge rates are valid for bedrock units.

Because of the large size of this basin, quality of near-surface groundwater is variable from one area to another. The sandstone aquifers of Mississippian age generally yield water of low to moderate iron content that contains less than 160 mg/l of hardness. Water from the sand and gravel deposits in the glaciated upper and western basin is very hard, ranging from 200 to 500 mg/l, with most analyses between 300 and 400 mg/l. This water also contains objectionable amounts of iron.

In the eastern basin, water is also quite hard when obtained from the sand and gravel and may also have high dissolved solids and chloride where induced infiltration from streams contaminated by industrial wastes and oil-field brines has occurred. The Muskingum River has, in the past, contained large amounts of dissolved solids and chlorides. Much of this problem has been remedied, but contamination can still be detected in wells that obtain large amounts of water from the valley fill. Water is available in very small quantities from some of the sandstone units in the Pennsylvanian and Permian section. The quality of this water is usually quite good, both in terms of softness and low chlorides. Care must be exercised in drilling in this complicated stratigraphic section because brines and coal seams are often encountered at relatively shallow depths, occasionally less than 100 feet deep.

## Hocking River Basin

The Hocking River originates in a mass of outwash in central Fairfield County and flows southeastward about 95 miles before entering the Ohio River at

Hockingport (Fig. 5-11). It drains 1200 square miles. Major tributaries include Federal (145 sq. mi. basin), Sunday (139 sq. mi.), Monday (116 sq. mi.), Clear (91 sq. mi.), and Rush Creeks (236 sq. mi.). With the exeption of Rush Creek, all of the major tributaries enter the mainstem from the northeast.

Raccoon and Symmes Creeks and the Little Scioto River, all of which drain directly into the Ohio River, are also included in this basin. Lengths and sizes of their respective drainage basins are 109 miles and 684 square miles and 356 and 41 and 233.

Bedrock in the basin consists of alternating layers of sandstone, shale and coal, with occasional layers of limestone. These rocks range in age from Mississippian to Permian.

Glacial deposits are found only in the northern part of the basin and, for the most part, are restricted to Fairfield County. Beyond the glacial margin, however, lie a few deposits of outwash. The most widespread of these extends several miles downstream from the headwaters of Hocking River to Nelsonville. From Nelsonville southward to the Ohio River, much of the outwash along the Hocking is covered by a few feet of alluvium. Both surficial and buried outwash also occur along Clear and Rush Creeks.

Ground-water supplies in the basin are obtained from outwash and sandstone aquifers. The most prolific sources, of course, are the outwash deposits along the Hocking River and Raccon Creek. Individual well yields in the vicinity of Lancaster and Logan and between Nelsonville and Chauncey should be as much as 1000 gpm and from Chauncey to nearby Coolville yields should range between 100 and 500 gpm. Throughout the rest of the upper half of the basin well yields would probably fall between 5 and 25 gpm, but south and east of Sunday Creek, where bedrock consists of Upper Pennsylvanian and Permian strata, individual yields are generally less than 5 gpm. The low yields are due largely to the relatively thin nature of the low permeability sandstones.

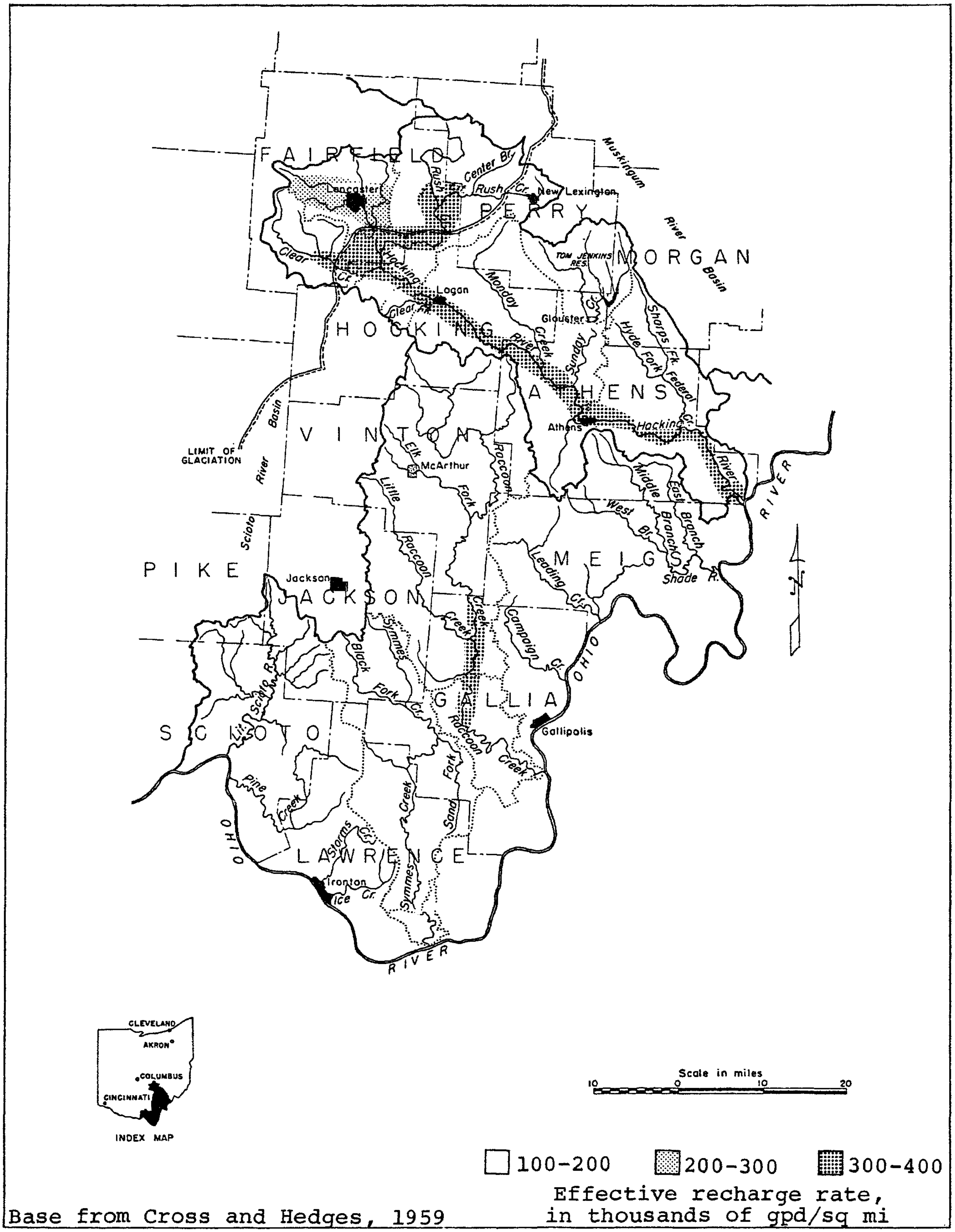



FIGURE 5-11. EFFECTIVE RECHARGE RATES IN THE HOCKING RIVER BASIN

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3156000 HUNTERS RUN AT LANCASTER, OHIO | | | | | | | | | | | | | | |
| 63 | 266000. | 264000. | 224000. | 51. | 50. | 43. | 5.59 | 5.56 | 4.72 | 11.04 | 1.58 | 2 | 21 | 2 |
| 67 | 465000. | 468000. | 440000. | 67. | 67. | 63. | 9.78 | 9.84 | 9.25 | 14.70 | 1.58 | 2 | 21 | 2 |
| 73 | 649000. | 631000. | 562000. | 70. | 68. | 61. | 13.63 | 13.25 | 11.81 | 19.48 | 1.58 | 2 | 21 | 2 |
| 3156400 HOCKING RIVER AT LANCASTER, OHIO | | | | | | | | | | | | | | |
| 63 | 222000. | 248000. | 217000. | 42. | 47. | 41. | 4.68 | 5.22 | 4.56 | 11.10 | 2.17 | 2 | 21 | 2 |
| 67 | 298000. | 306000. | 274000. | 54. | 56. | 50. | 6.26 | 6.43 | 5.76 | 11.50 | 2.17 | 2 | 21 | 2 |
| 73 | 483000. | 490000. | 469000. | 54. | 55. | 53. | 10.15 | 10.29 | 9.86 | 18.77 | 2.17 | 2 | 21 | 2 |
| 3157000 CLEAR CREEK NEAR ROCKBRIDGE, OHIO | | | | | | | | | | | | | | |
| 63 | 330000. | 352000. | 313000. | 56. | 60. | 53. | 6.94 | 7.40 | 6.59 | 12.39 | 2.45 | 3 | 90 | 2 |
| 67 | 383000. | 396000. | 389000. | 56. | 58. | 57. | 8.06 | 8.32 | 8.18 | 14.32 | 2.45 | 3 | 90 | 2 |
| 73 | 500000. | 502000. | 477000. | 57. | 57. | 54. | 10.51 | 10.55 | 10.03 | 18.58 | 2.45 | 3 | 90 | 2 |
| 3157500 HOCKING RIVER AT ENTERPRISE, OHIO | | | | | | | | | | | | | | |
| 63 | 287000. | 290000. | 233000. | 48. | 49. | 39. | 6.04 | 6.10 | 4.91 | 12.57 | 3.41 | 3 | 90 | 2 |
| 67 | 399000. | 395000. | 390000. | 55. | 54. | 54. | 8.40 | 8.30 | 8.20 | 15.27 | 3.41 | 3 | 90 | 2 |
| 73 | 546000. | 549000. | 560000. | 59. | 59. | 60. | 11.48 | 11.54 | 11.78 | 19.50 | 3.41 | 3 | 90 | 2 |
| 3159000 SUNDAY CREEK AT GLOUSTER, OHIO | | | | | | | | | | | | | | |
| 63 | 237000. | 252000. | 212000. | 36. | 39. | 32. | 4.99 | 5.31 | 4.45 | 13.76 | 2.53 | 3 | 90 | 1 |
| 67 | 409000. | 406000. | 335000. | 51. | 51. | 42. | 8.61 | 8.53 | 7.05 | 16.73 | 2.53 | 3 | 90 | 1 |
| 73 | 484000. | 493000. | 468000. | 57. | 58. | 55. | 10.18 | 10.37 | 9.84 | 17.74 | 2.53 | 3 | 90 | 1 |

TABLE 5-23. RECHARGE STATISTICS FOR THE HOCKING RIVER BASIN

TABLE 5-23 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3159500 HOCKING RIVER AT ATHENS, OHIO | | | | | | | | | | | | | | |
| 63 | 302000. | 292000. | 267000. | 48. | 46. | 42. | 6.35 | 6.14 | 5.62 | 13.28 | 3.93 | 3 | 21 | 1 |
| 67 | 428000. | 423000. | 386000. | 57. | 56. | 51. | 9.00 | 8.90 | 8.13 | 15.84 | 3.93 | 3 | 21 | 1 |
| 73 | 582000. | 579000. | 541000. | 60. | 59. | 55. | 12.22 | 12.18 | 11.38 | 20.54 | 3.93 | 3 | 21 | 1 |
| 3159540 SHADE RIVER NEAR CHESTER, OHIO | | | | | | | | | | | | | | |
| 67 | 244000. | 259000. | 185000. | 35. | 37. | 27. | 5.14 | 5.44 | 3.89 | 14.67 | 2.75 | 3 | 90 | 1 |
| 73 | 376000. | 384000. | 338000. | 42. | 42. | 37. | 7.91 | 8.07 | 7.10 | 19.05 | 2.75 | 3 | 90 | 1 |
| 3201600 SANDY RUN ABOVE BIG FOUR HOLLOW CREEK NEAR L. HOPE, O | | | | | | | | | | | | | | |
| 73 | 530000. | 540000. | 466000. | 59. | 60. | 52. | 11.15 | 11.36 | 9.79 | 19.01 | 1.00 | 3 | 90 | 1 |
| 3201700 BIG FOUR HOLLOW CREEK NEAR LAKE HOPE, OHIO | | | | | | | | | | | | | | |
| 73 | 515000. | 522000. | 462000. | 57. | 58. | 51. | 10.83 | 10.97 | 9.71 | 19.05 | 1.00 | 3 | 90 | 1 |
| 3201800 SANDY RUN NEAR LAKE HOPE, OHIO | | | | | | | | | | | | | | |
| 63 | 400000. | 427000. | 373000. | 44. | 47. | 41. | 8.42 | 8.99 | 7.84 | 19.02 | 1.37 | 3 | 90 | 1 |
| 67 | 414000. | 402000. | 312000. | 53. | 52. | 40. | 8.70 | 8.45 | 6.56 | 16.28 | 1.37 | 3 | 90 | 1 |
| 73 | 2849000. | 2908000. | 2580000. | 60. | 61. | 55. | 59.85 | 61.09 | 54.19 | 99.39 | 1.00 | 3 | 90 | 1 |
| 3202000 RACCOON CREEK AT ADAMSVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 365000. | 333000. | 264000. | 52. | 47. | 38. | 7.67 | 7.00 | 5.55 | 14.75 | 3.58 | 3 | 90 | 1 |
| 67 | 397000. | 407000. | 367000. | 54. | 56. | 50. | 8.34 | 8.57 | 7.71 | 15.36 | 3.58 | 3 | 90 | 1 |
| 73 | 521000. | 521000. | 463000. | 62. | 62. | 55. | 10.95 | 10.95 | 9.73 | 17.73 | 3.58 | 3 | 90 | 1 |

HOCKING-RACCOON BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 3157500 HOCKING RIVER AT ENTERPRISE, OHIO | | | | | | | | | | | | |
| FX | 81000. | 168000. | 214000. | 269000. | 293000. | 1330000. | 458000. | 282000. | 128000. | 81000. | 77000. | 55000. |
| SL | 84000. | 165000. | 220000. | 282000. | 294000. | 1318000. | 483000. | 289000. | 133000. | 81000. | 78000. | 53000. |
| LM | 93000. | 162000. | 217000. | 231000. | 236000. | 849000. | 403000. | 264000. | 126000. | 79000. | 78000. | 56000. |
| 67 | | | | | | | | | | | | |
| FX | 111000. | 330000. | 336000. | 233000. | 445000. | 1399000. | 686000. | 745000. | 199000. | 108000. | 83000. | 61000. |
| SL | 115000. | 332000. | 460000. | 228000. | 446000. | 1236000. | 666000. | 786000. | 195000. | 107000. | 82[illegible] | 56000. |
| LM | 109000. | 313000. | 272000. | 257000. | 419000. | 1352000. | 657000. | 833000. | 215000. | 108000. | 83000. | 56000. |
| 73 | | | | | | | | | | | | |
| FX | 217000. | 761000. | 985000. | 601000. | 619000. | 581000. | 1090000. | 655000. | 425000. | 385000. | 181000. | 115000. |
| SL | 216000. | 809000. | 979000. | 627000. | 631000. | 607000. | 1126000. | 643000. | 384000. | 285000. | 183000. | 113000. |
| LM | 200000. | 837000. | 994000. | 658000. | 598000. | 572000. | 1166000. | 696000. | 357000. | 340000. | 197000. | 113000. |
| 67 3159540 SHADE RIVER NEAR CHESTER, OHIO | | | | | | | | | | | | |
| FX | 23000. | 121000. | 226000. | 126000. | 305000. | 1048000. | 364000. | 539000. | 78000. | 59000. | 27000. | 8907. |
| SL | 25000. | 128000. | 298000. | 125000. | 306000. | 1126000. | 376000. | 540000. | 71000. | 66000. | 25000. | 8783. |
| LM | 16000. | 95000. | 94000. | 115000. | 306000. | 672000. | 359000. | 420000. | 57000. | 52000. | 24000. | 7793. |
| 73 | | | | | | | | | | | | |
| FX | 48000. | 247000. | 745000. | 490000. | 473000. | 430000. | 1104000. | 526000. | 205000. | 155000. | 72000. | 37000. |
| SL | 44000. | 298000. | 794000. | 464000. | 497000. | 473000. | 1004000. | 559000. | 207000. | 161000. | 79000. | 37000. |
| LM | 38000. | 247000. | 699000. | 422000. | 470000. | 394000. | 844000. | 515000. | 207000. | 123000. | 68000. | 37000. |
| 63 3202000 RACCOON CREEK AT ADAMSVILLE, OHIO | | | | | | | | | | | | |
| FX | 23000. | 245000. | 310000. | 369000. | 507000. | 2173000. | 357000. | 234000. | 75000. | 30000. | 21000. | 10000. |
| SL | 33000. | 245000. | 332000. | 369000. | 499000. | 1754000. | 373000. | 251000. | 71000. | 29000. | 22000. | 9939. |
| LM | 40000. | 229000. | 311000. | 321000. | 489000. | 982000. | 405000. | 271000. | 72000. | 26000. | 21000. | 10000. |
| 67 | | | | | | | | | | | | |
| FX | 45000. | 201000. | 402000. | 194000. | 429000. | 1805000. | 710000. | 796000. | 113000. | 32000. | 15000. | 3839. |
| SL | 46000. | 208000. | 407000. | 177000. | 428000. | 1775000. | 720000. | 949000. | 117000. | 32000. | 15000. | 3243. |
| LM | 40000. | 181000. | 212000. | 190000. | 427000. | 1599000. | 712000. | 862000. | 121000. | 31000. | 14000. | 4203. |
| 73 | | | | | | | | | | | | |
| FX | 90000. | 484000. | 1120000. | 575000. | 779000. | 603000. | 1293000. | 809000. | 292000. | 129000. | 66000. | 33000. |
| SL | 92000. | 504000. | 1033000. | 573000. | 745000. | 585000. | 1514000. | 749000. | 275000. | 110000. | 68000. | 32000. |
| LM | 78000. | 499000. | 815000. | 589000. | 754000. | 557000. | 1308000. | 475000. | 295000. | 123000. | 66000. | 34000. |

TABLE 5-24. MONTHLY RECHARGE RATES FOR THE HOCKING RIVER BASIN

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3156000 HUNTERS RUN AT LANCASTER, OHIO | | | | | | | | | |
| 63 | 3.31663 | 1.74532 | 0.08000 | 0.09000 | 0.16250 | 0.25000 | 0.30000 | 0 | 0 |
| 67 | 4.56435 | 2.42384 | 0.12000 | 0.12000 | 0.20000 | 0.40000 | 0.55000 | 0 | 0 |
| 73 | 3.13172 | 1.72345 | 0.22000 | 0.26000 | 0.50500 | 0.97000 | 1.10000 | 0 | 0 |
| 3156400 HOCKING RIVER AT LANCASTER, OHIO | | | | | | | | | |
| 63 | 3.09337 | 1.92318 | 0.09751 | 0.12033 | 0.15145 | 0.22822 | 0.29046 | 0 | 0 |
| 67 | 3.93212 | 1.96214 | 0.10373 | 0.13485 | 0.20747 | 0.33195 | 0.40456 | 0 | 0 |
| 73 | 2.70801 | 1.58698 | 0.24896 | 0.34232 | 0.56017 | 0.70539 | 0.88174 | 0 | 0 |
| 3157000 CLEAR CREEK NEAR ROCKBRIDGE, OHIO | | | | | | | | | |
| 63 | 3.10728 | 1.84961 | 0.14607 | 0.16292 | 0.21348 | 0.31461 | 0.39326 | 0 | 0 |
| 67 | 4.03113 | 2.21241 | 0.13483 | 0.15730 | 0.21348 | 0.34831 | 0.43820 | 0 | 0 |
| 73 | 3.67921 | 1.92627 | 0.21348 | 0.23034 | 0.42697 | 0.74157 | 0.89888 | 0 | 0 |
| 3157500 HOCKING RIVER AT ENTERPRISE, OHIO | | | | | | | | | |
| 63 | 3.68030 | 2.19876 | 0.10893 | 0.12200 | 0.14815 | 0.25054 | 0.35512 | 0 | 0 |
| 67 | 5.10754 | 2.43780 | 0.09804 | 0.12527 | 0.20969 | 0.36383 | 0.47277 | 0 | 0 |
| 73 | 3.32424 | 1.95599 | 0.20261 | 0.27996 | 0.47549 | 0.78431 | 1.05338 | 0 | 0 |
| 3159000 SUNDAY CREEK AT GLOUSTER, OHIO | | | | | | | | | |
| 63 | 5.26444 | 2.55841 | 0.05769 | 0.06731 | 0.10577 | 0.16346 | 0.23558 | 0 | 0 |
| 67 | 7.86423 | 3.27236 | 0.05577 | 0.06250 | 0.11538 | 0.23077 | 0.31731 | 0 | 0 |
| 73 | 8.02408 | 3.12485 | 0.04135 | 0.05481 | 0.16346 | 0.49038 | 0.81731 | 0 | 0 |

TABLE 5-25. FLOW-RATIO STATISTICS FOR THE HOCKING RIVER BASIN

TABLE 5-25 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3159500 HOCKING RIVER AT ATHENS, OHIO | | | | | | | | | |
| 63 | 4.57676 | 2.51922 | 0.07317 | 0.08961 | 0.12089 | 0.23860 | 0.34199 | 0 | 0 |
| 67 | 6.05381 | 2.79991 | 0.07741 | 0.09809 | 0.17179 | 0.31389 | 0.45122 | 0 | 0 |
| 73 | 4.20571 | 2.17286 | 0.15058 | 0.19035 | 0.40429 | 0.80594 | 1.07105 | 0 | 0 |
| 3159540 SHADE RIVER NEAR CHESTER, OHIO | | | | | | | | | |
| 67 | 9.80064 | 3.59891 | 0.01795 | 0.02436 | 0.06026 | 0.16667 | 0.26603 | 0 | 0 |
| 73 | 6.36396 | 2.58934 | 0.06410 | 0.07692 | 0.23878 | 0.57051 | 0.72115 | 0 | 0 |
| 3201600 SANDY RUN ABOVE BIG FOUR HOLLOW CREEK NEAR L. HOPE, O. | | | | | | | | | |
| 73 | 8.18535 | 3.72526 | 0.05102 | 0.05102 | 0.12500 | 0.40816 | 0.67347 | 0 | 0 |
| 3201700 BIG FOUR HOLLOW CREEK NEAR LAKE HOPE, OHIO | | | | | | | | | |
| 73 | 10.24695 | 3.61403 | 0.01980 | 0.02970 | 0.12129 | 0.47525 | 0.73267 | 0 | 6 |
| 3201800 SANDY RUN NEAR LAKE HOPE, OHIO | | | | | | | | | |
| 63 | 10.95445 | 3.52668 | 0.0 | 0.02041 | 0.08163 | 0.28571 | 0.51020 | 0 | 32 |
| 67 | 20.00000 | 4.66252 | 0.0 | 0.00612 | 0.18776 | 0.42857 | 0.65306 | 61 | 33 |
| 73 | 16.83250 | 3.65148 | 0.0 | 0.06122 | 0.64286 | 2.75510 | 3.97959 | 0 | 27 |
| 3202000 RACCOON CREEK AT ADAMSVILLE, OHIO | | | | | | | | | |
| 63 | 8.39973 | 4.00459 | 0.02222 | 0.03077 | 0.05812 | 0.19316 | 0.32479 | 0 | 0 |
| 67 | 13.00641 | 4.28200 | 0.00650 | 0.02051 | 0.06496 | 0.22564 | 0.37949 | 0 | 0 |
| 73 | 5.13030 | 2.96633 | 0.07179 | 0.10684 | 0.19573 | 0.65812 | 0.90940 | 0 | 0 |

Except for the wide flood plains along several of the major water courses, relief is moderate to high. Gradients of some of the larger streams range from 8 to 20 feet per mile.

Annual precipitation in the basin during the study years was about 32 to 36 inches (1963), 34 to 37 inches (1967) and 39 to 46 inches (1973).

Throughout the basin the spring runoff, which generally occurs in March, provides the largest flows. Low flows usually occur in late summer.

Effective ground-water recharge rates throughout the basin are shown in Table 5-23. They ranged from a high to 440,000 along the outwash are above Lancaster to a low of 185,000 gpd/sq. mi. in Meigs County. The calculated rate for Raccoon Creek is too high and is influenced by coal mining. The average rate throughout the basin ranges between 100,000 and 200,000 gpd/sq. mi.

During 1967 monthly recharge rates at Enterprise ranged from a low of 36,000 (September) to a high of 1,352,000 gpd/sq. mi. in March. Along Shade River they ranged from a low 7793 in September to a high of 672,000 gpd/sq. mi. in March (Table 5-24).

Flow ratios are moderately high where streams drain outwash, but low elsewhere (Table 6-25).

## Scioto River Basin

The Scioto River originates in central Ohio in a swampy till plain fed by adjacent morainal deposits (Fig. 5-12). The river flows southward through the Glaciated Plateau and finally empties into the Ohio River at Portsmouth after passing through the rugged Unglaciated Plateau. The Scioto is about 240 miles long and drains 6,510 square miles. Major tributaries include Little Scioto River (110 sq. mi.), Mill Creek (185 sq. mi.), Olentangy River (536 sq. mi.), Big Walnut Creek (557 sq. mi.), Salt Creek (553 sq. mi.), Sunfish Creek (145 sq. mi.), and Scioto Brush Creek (274 sq. mi.).

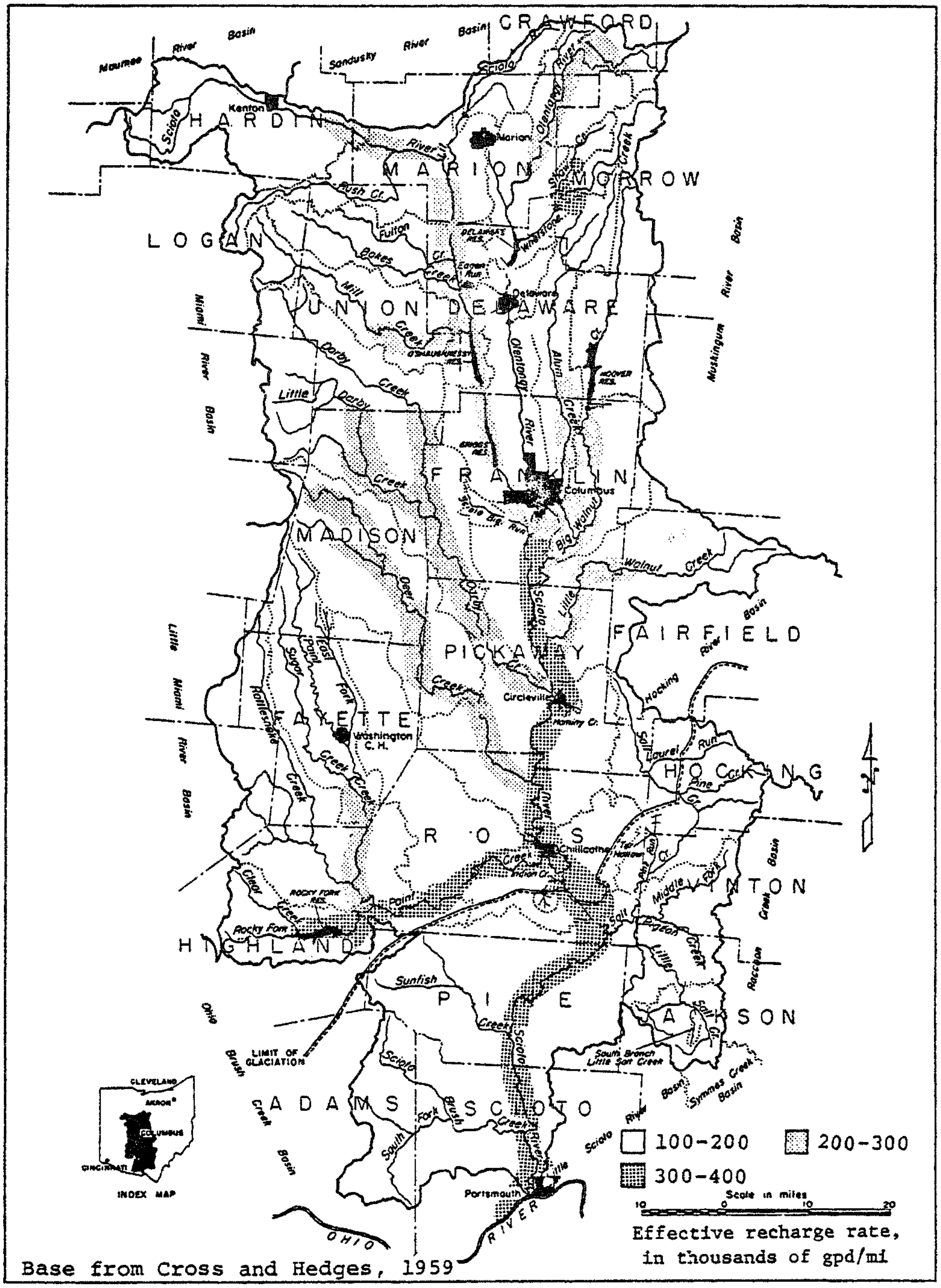



FIGURE 5-12. EFFECTIVE RECHARGE RATES IN THE SCIOTO RIVER BASIN

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3218000 LITTLE SCIOTO RIVER ABOVE MARION, OHIO | | | | | | | | | |
| 63 | 21.90891 | 5.00000 | 0.0 | 0.00207 | 0.01105 | 0.06906 | 0.11050 | 0 | 28 |
| 67 | 17.40842 | 6.01533 | 0.00677 | 0.00905 | 0.02624 | 0.12983 | 0.25552 | 0 | 0 |
| 3219500 SCIOTO RIVER NEAR PROSPECT, OHIO | | | | | | | | | |
| 63 | 5.87367 | 2.36643 | 0.02116 | 0.02469 | 0.04409 | 0.06526 | 0.09788 | 0 | 0 |
| 67 | 8.64769 | 3.97391 | 0.03351 | 0.04056 | 0.06570 | 0.16578 | 0.26984 | 0 | 0 |
| 73 | 4.64397 | 2.41609 | 0.08466 | 0.15256 | 0.35273 | 0.59612 | 0.85538 | 0 | 0 |
| 3220000 MILL CREEK NEAR BELLEPOINT, OHIO | | | | | | | | | |
| 63 | 6.76679 | 2.27866 | 0.00618 | 0.01067 | 0.02921 | 0.04831 | 0.06180 | 0 | 0 |
| 67 | 11.90874 | 3.90191 | 0.01517 | 0.02163 | 0.04059 | 0.08989 | 0.12921 | 0 | 0 |
| 73 | 5.88172 | 2.52370 | 0.06742 | 0.10393 | 0.23595 | 0.38202 | 0.71910 | 0 | 0 |
| 3221000 SCIOTO RIVER BELOW O'SHAUGHNESSY DAM, NEAR DUBLIN, OHIO | | | | | | | | | |
| 63 | 3.86067 | 2.00000 | 0.02449 | 0.04286 | 0.05408 | 0.07857 | 0.09031 | 0 | 0 |
| 67 | 8.33970 | 3.64251 | 0.03980 | 0.04541 | 0.07143 | 0.15408 | 0.26020 | 0 | 0 |
| 73 | 4.80863 | 2.38620 | 0.09490 | 0.15357 | 0.37679 | 0.59796 | 0.90765 | 0 | 0 |
| 3223000 OLENTANGY RIVER AT CLARION, OHIO | | | | | | | | | |
| 63 | 8.60663 | 2.69740 | 0.00637 | 0.01720 | 0.04443 | 0.10191 | 0.12739 | 0 | 0 |
| 67 | 12.56161 | 4.92922 | 0.01783 | 0.02166 | 0.03965 | 0.14013 | 0.25478 | 0 | 0 |
| 73 | 7.14435 | 2.26975 | 0.04841 | 0.07643 | 0.35669 | 0.57325 | 0.78662 | 0 | 0 |

TABLE 5-26. FLOW-RATIO STATISTICS FOR THE SCIOTO RIVER BASIN

TABLE 5-26 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3224500 WHETSTONE CREEK NEAR ASHLEY, OHIO | | | | | | | | | |
| 63 | 7.37497 | 2.40057 | 0.00608 | 0.02077 | 0.05978 | 0.12158 | 0.15198 | 0 | 0 |
| 67 | 8.00436 | 3.50193 | 0.03546 | 0.04357 | 0.07497 | 0.17224 | 0.28369 | 0 | 0 |
| 73 | 4.70704 | 1.92241 | 0.07396 | 0.16211 | 0.46606 | 0.66869 | 0.91185 | 0 | 0 |
| 3225500 OLENTANGY RIVER NEAR DELAWARE, OHIO | | | | | | | | | |
| 63 | 4.18757 | 1.80834 | 0.02799 | 0.03562 | 0.08715 | 0.11196 | 0.12468 | 0 | 0 |
| 67 | 10.50973 | 3.47825 | 0.02545 | 0.02799 | 0.07125 | 0.10687 | 0.22519 | 0 | 0 |
| 73 | 5.97052 | 2.28529 | 0.06616 | 0.10814 | 0.41730 | 0.67176 | 0.85623 | 0 | 0 |
| 3226800 OLENTANGY RIVER NEAR WORTHINGTON, OHIO | | | | | | | | | |
| 63 | 4.67440 | 1.94936 | 0.02817 | 0.04024 | 0.08048 | 0.10463 | 0.12475 | 0 | 0 |
| 67 | 9.30949 | 3.43981 | 0.03018 | 0.03924 | 0.08099 | 0.12475 | 0.28873 | 0 | 0 |
| 73 | 5.42545 | 2.21555 | 0.08048 | 0.12475 | 0.44064 | 0.71227 | 0.96177 | 0 | 0 |
| 3227500 SCIOTO RIVER AT COLUMBUS, OHIO | | | | | | | | | |
| 63 | 2.87393 | 1.73870 | 0.09085 | 0.09699 | 0.11971 | 0.14856 | 0.17680 | 0 | 0 |
| 67 | 5.59866 | 2.71093 | 0.08963 | 0.10497 | 0.14242 | 0.25537 | 0.36832 | 0 | 0 |
| 73 | 3.87808 | 2.11679 | 0.16575 | 0.23327 | 0.49217 | 0.76734 | 1.01596 | 0 | 0 |
| 3228500 BIG WALNUT CREEK AT CENTRAL COLLEGE, OHIO | | | | | | | | | |
| 63 | 1.54110 | 1.15063 | 0.32105 | 0.33684 | 0.37368 | 0.38947 | 0.40526 | 0 | 0 |
| 67 | 2.61063 | 1.59937 | 0.33158 | 0.34211 | 0.36316 | 0.39474 | 0.42105 | 0 | 0 |
| 73 | 2.80372 | 1.86653 | 0.47895 | 0.51053 | 0.57368 | 0.63684 | 0.78158 | 0 | 0 |

TABLE 5-26 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3228805 ALUM CREEK AT AFRICA, OHIO | | | | | | | | | |
| 67 | 14.79865 | 3.82828 | 0.00902 | 0.01639 | 0.06250 | 0.15574 | 0.24590 | 0 | 0 |
| 73 | 7.36142 | 2.36993 | 0.03279 | 0.08607 | 0.39549 | 0.63115 | 0.95902 | 0 | 0 |
| 3229000 ALUM CREEK AT COLUMBUS, OHIO | | | | | | | | | |
| 63 | 6.48791 | 2.25462 | 0.01429 | 0.02275 | 0.06349 | 0.12169 | 0.15873 | 0 | 0 |
| 67 | 6.68104 | 2.66129 | 0.04815 | 0.05820 | 0.12831 | 0.22751 | 0.29101 | 0 | 0 |
| 73 | 5.42105 | 2.20096 | 0.07937 | 0.12963 | 0.42460 | 0.70370 | 1.00529 | 0 | 0 |
| 3229500 BIG WALNUT CREEK AT REES, OHIO | | | | | | | | | |
| 63 | 4.41876 | 1.89710 | 0.04412 | 0.05423 | 0.09053 | 0.12868 | 0.15441 | 0 | 0 |
| 67 | 6.17262 | 2.42084 | 0.04779 | 0.07261 | 0.13833 | 0.22426 | 0.28676 | 0 | 0 |
| 73 | 3.95410 | 2.16090 | 0.16728 | 0.23162 | 0.38235 | 0.68015 | 0.94393 | 0 | 0 |
| 3230500 BIG DARBY CREEK AT DARBYVILLE, OHIO | | | | | | | | | |
| 63 | 5.70909 | 2.66440 | 0.01610 | 0.02996 | 0.04728 | 0.07491 | 0.11236 | 0 | 0 |
| 67 | 6.93078 | 2.97368 | 0.03558 | 0.05243 | 0.10721 | 0.22472 | 0.33801 | 0 | 0 |
| 73 | 3.82467 | 1.97657 | 0.17603 | 0.22659 | 0.49251 | 0.81648 | 1.12734 | 0 | 0 |
| 3230800 DEER CREEK AT MOUNT STIRLING, OHIO | | | | | | | | | |
| 67 | 6.23928 | 2.90912 | 0.04035 | 0.06140 | 0.11842 | 0.23246 | 0.38377 | 0 | 0 |
| 73 | 3.51768 | 1.99549 | 0.18421 | 0.28728 | 0.54825 | 0.78070 | 1.08553 | 0 | 0 |

TABLE 5-26 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3230900 DEER CREEK NEAR PANCOASTBURG, OHIO | | | | | | | | | |
| 67 | 7.03562 | 3.17896 | 0.04332 | 0.05054 | 0.09386 | 0.24549 | 0.37004 | 0 | 0 |
| 73 | 4.44386 | 2.17227 | 0.12635 | 0.21480 | 0.46209 | 0.74007 | 1.03610 | 0 | 0 |
| 3231000 DEER CREEK AT WILLIAMSPORT, OHIO | | | | | | | | | |
| 63 | 4.65580 | 2.37889 | 0.03604 | 0.05105 | 0.06607 | 0.10811 | 0.16517 | 0 | 0 |
| 67 | 7.65724 | 3.16228 | 0.03904 | 0.04505 | 0.09009 | 0.21922 | 0.36486 | 0 | 0 |
| 73 | 4.49569 | 2.12779 | 0.19820 | 0.21321 | 0.54655 | 0.84985 | 1.13513 | 0 | 0 |
| 3231500 SCIOTO RIVER AT CHILLICOTHE, OHIO | | | | | | | | | |
| 63 | 3.48911 | 1.81575 | 0.08756 | 0.10158 | 0.11899 | 0.15588 | 0.20005 | 0 | 0 |
| 67 | 4.98888 | 2.45240 | 0.10392 | 0.11691 | 0.18187 | 0.29618 | 0.39880 | 0 | 0 |
| 73 | 3.07417 | 1.90604 | 0.21434 | 0.35464 | 0.63003 | 0.98467 | 1.27306 | 0 | 0 |
| 3232000 PAINT CREEK NEAR GREENFIELD, OHIO | | | | | | | | | |
| 67 | 15.78313 | 4.40170 | 0.00325 | 0.01124 | 0.04819 | 0.20080 | 0.30723 | 0 | 0 |
| 73 | 4.25064 | 2.19495 | 0.14859 | 0.20683 | 0.49598 | 0.76305 | 1.11044 | 0 | 0 |
| 3232300 RATTLESNAKE CREEK NEAR CENTERFIELD, OHIO | | | | | | | | | |
| 73 | 5.52964 | 2.36925 | 0.07177 | 0.12440 | 0.35885 | 0.64593 | 0.94976 | 0 | 0 |
| 3232470 PAINT CREEK NEAR BAINBRIDGE, OHIO | | | | | | | | | |
| 73 | 4.50209 | 2.06380 | 0.09298 | 0.16316 | 0.47368 | 0.75439 | 1.07018 | 0 | 0 |

TABLE 5-26 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3232500 ROCKY FORK NEAR BARRETTS MILLS, OHIO | | | | | | | | | |
| 63 | 3.94757 | 1.86501 | 0.07143 | 0.08571 | 0.16429 | 0.25714 | 0.40000 | 0 | 0 |
| 67 | 8.28653 | 4.35923 | 0.02357 | 0.03214 | 0.06089 | 0.18571 | 0.32857 | 0 | 0 |
| 73 | 4.25354 | 2.04226 | 0.14286 | 0.19286 | 0.50179 | 0.98571 | 1.31429 | 0 | 0 |
| 3234000 PAINT CREEK NEAR BOURNEVILLE, OHIO | | | | | | | | | |
| 63 | 4.97107 | 2.65998 | 0.05576 | 0.06444 | 0.08209 | 0.14994 | 0.27943 | 0 | 0 |
| 67 | 8.74537 | 3.87845 | 0.02478 | 0.03346 | 0.07311 | 0.20074 | 0.33581 | 0 | 0 |
| 73 | 4.49256 | 1.97772 | 0.13507 | 0.16914 | 0.48947 | 0.76456 | 0.98203 | 0 | 0 |
| 3234500 SCIOTO RIVER AT HIGBY, OHIO | | | | | | | | | |
| 63 | 3.48699 | 1.97787 | 0.09277 | 0.10290 | 0.11733 | 0.16761 | 0.23582 | 0 | 0 |
| 67 | 4.93442 | 2.33912 | 0.09082 | 0.11966 | 0.19636 | 0.32937 | 0.42877 | 0 | 0 |
| 73 | 3.12039 | 1.85825 | 0.23972 | 0.33327 | 0.66459 | 0.97057 | 1.27363 | 0 | 0 |
| 3235500 TAR HOLLOW CREEK AT TAR HOLLOW STATE PARK, OHIO | | | | | | | | | |
| 63 | 45.57326 | 21.48344 | 0.0 | 0.00100 | 0.00100 | 0.0 | 0.15385 | 0 | 159 |
| 67 | 57.51253 | 32.52217 | 0.0 | 0.00100 | 0.00100 | 0.0 | 0.13846 | 0 | 150 |
| 73 | 59.00406 | 4.38529 | 0.0 | 0.00100 | 0.09630 | 0.42963 | 0.74074 | 0 | 37 |
| 3237280 UPPER TWIN CREEK AT MCGAW,OHIO | | | | | | | | | |
| 67 | 49.21254 | 7.55929 | 0.0 | 0.00100 | 0.01641 | 0.05937 | 0.17969 | 0 | 40 |
| 73 | 36.51483 | 4.44972 | 0.00082 | 0.00246 | 0.10246 | 0.45902 | 0.62295 | 0 | 0 |

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3218000 LITTLE SCIOTO RIVER ABOVE MARION, OHIO | | | | | | | | | | | | | | |
| 63 | 182000. | 165000. | 126000. | 47. | 43. | 33. | 3.84 | 3.48 | 2.65 | 8.10 | 2.35 | 1 | 10 | 4 |
| 67 | 289000. | 297000. | 223000. | 50. | 52. | 39. | 6.09 | 6.25 | 4.70 | 12.09 | 2.35 | 1 | 10 | 4 |
| 3219500 SCIOTO RIVER NEAR PROSPECT, OHIO | | | | | | | | | | | | | | |
| 63 | 165000. | 177000. | 154000. | 43. | 46. | 40. | 3.48 | 3.73 | 3.25 | 8.06 | 3.55 | 1 | 10 | 4 |
| 67 | 253000. | 273000. | 217000. | 41. | 44. | 35. | 5.33 | 5.75 | 4.57 | 12.92 | 3.55 | 1 | 10 | 4 |
| 73 | 457000. | 459000. | 402000. | 49. | 50. | 43. | 9.61 | 9.66 | 8.45 | 19.50 | 3.55 | 1 | 10 | 4 |
| 3220000 MILL CREEK NEAR BELLEPOINT, OHIO | | | | | | | | | | | | | | |
| 63 | 125000. | 119000. | 89000. | 37. | 35. | 26. | 2.64 | 2.51 | 1.88 | 7.24 | 2.82 | 1 | 10 | 4 |
| 67 | 217000. | 227000. | 220000. | 34. | 36. | 35. | 4.57 | 4.77 | 4.63 | 13.35 | 2.82 | 1 | 10 | 4 |
| 73 | 382000. | 361000. | 318000. | 44. | 42. | 37. | 8.02 | 7.59 | 6.69 | 18.21 | 2.82 | 1 | 10 | 4 |
| 3221000 SCIOTO RIVER BELOW O'SHAUGHNESSY DAM, NEAR DUBLIN, OH | | | | | | | | | | | | | | |
| 63 | 191000. | 170000. | 103000. | 51. | 45. | 28. | 4.01 | 3.58 | 2.18 | 7.94 | 3.97 | 1 | 13 | 3 |
| 67 | 246000. | 271000. | 215000. | 40. | 44. | 35. | 5.17 | 5.70 | 4.52 | 12.96 | 3.97 | 1 | 13 | 3 |
| 73 | 484000. | 472000. | 417000. | 50. | 49. | 43. | 10.18 | 9.92 | 8.78 | 20.19 | 3.97 | 1 | 13 | 3 |
| 3223000 OLENTANGY RIVER AT CLARION, OHIO | | | | | | | | | | | | | | |
| 63 | 243000. | 207000. | 172000. | 50. | 43. | 35. | 5.12 | 4.36 | 3.63 | 10.23 | 2.75 | 1 | 10 | 3 |
| 67 | 313000. | 322000. | 245000. | 43. | 45. | 34. | 6.58 | 6.77 | 5.16 | 15.17 | 2.75 | 1 | 10 | 3 |
| 73 | 433000. | 433000. | 395000. | 45. | 45. | 41. | 9.11 | 9.11 | 8.30 | 20.27 | 2.75 | 1 | 10 | 3 |

TABLE 5-27. RECHARGE STATISTICS FOR THE SCIOTO RIVER BASIN

TABLE 5-27 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3224500 WHETSTONE CREEK NEAR ASHLEY, OHIO | | | | | | | | | | | | | | |
| 63 | 218000. | 189000. | 145000. | 43. | 37. | 28. | 4.58 | 3.97 | 3.06 | 10.75 | 2.51 | 1 | 10 | 3 |
| 67 | 280000. | 293000. | 281000. | 41. | 43. | 41. | 5.90 | 6.16 | 6.43 | 14.44 | 2.51 | 1 | 10 | 3 |
| 73 | 502000. | 491000. | 453000. | 47. | 46. | 42. | 10.56 | 10.32 | 9.52 | 22.52 | 2.51 | 1 | 10 | 3 |
| 3225500 OLENTANGY RIVER NEAR DELAWARE, OHIO | | | | | | | | | | | | | | |
| 63 | 180000. | 129000. | 62000. | 44. | 32. | 15. | 3.79 | 2.73 | 1.31 | 8.64 | 3.30 | 1 | 13 | 3 |
| 67 | 210000. | 171000. | 123000. | 32. | 26. | 19. | 4.41 | 3.61 | 2.60 | 13.74 | 3.30 | 1 | 13 | 3 |
| 73 | 382000. | 361000. | 315000. | 37. | 35. | 30. | 8.04 | 7.60 | 6.63 | 21.83 | 3.30 | 1 | 13 | 3 |
| 3226800 OLENTANGY RIVER NEAR WORTHINGTON, OHIO | | | | | | | | | | | | | | |
| 63 | 188000. | 141000. | 81000. | 46. | 35. | 20. | 3.96 | 2.96 | 1.70 | 8.58 | 3.46 | 1 | 10 | 3 |
| 67 | 222000. | 205000. | 183000. | 33. | 31. | 27. | 4.67 | 4.31 | 3.85 | 14.06 | 3.46 | 1 | 10 | 3 |
| 73 | 415000. | 416000. | 356000. | 41. | 41. | 35. | 8.73 | 8.75 | 7.49 | 21.25 | 3.46 | 1 | 10 | 3 |
| 3227500 SCIOTO RIVER AT COLUMBUS, OHIO | | | | | | | | | | | | | | |
| 63 | 220000. | 241000. | 241000. | 51. | 56. | 57. | 4.62 | 5.07 | 5.08 | 8.98 | 4.39 | 1 | 20 | 3 |
| 67 | 246000. | 290000. | 241000. | 37. | 43. | 36. | 5.18 | 6.11 | 6.14 | 14.08 | 4.39 | 1 | 20 | 3 |
| 73 | 467000. | 465000. | 401000. | 47. | 47. | 40. | 9.83 | 9.78 | 9.79 | 20.95 | 4.39 | 1 | 20 | 3 |
| 3228500 BIG WALNUT CREEK AT CENTRAL COLLEGE, OHIO | | | | | | | | | | | | | | |
| 63 | 351000. | 350000. | 328000. | 65. | 65. | 61. | 7.39 | 7.36 | 6.89 | 11.30 | 2.86 | 1 | 13 | 3 |
| 67 | 382000. | 378000. | 353000. | 54. | 53. | 50. | 8.03 | 7.95 | 7.43 | 14.87 | 2.86 | 1 | 13 | 3 |
| 73 | 632000. | 585000. | 526000. | 55. | 51. | 46. | 13.29 | 12.31 | 11.05 | 24.10 | 2.86 | 1 | 13 | 3 |

TABLE 5-27 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3228805 ALUM CREEK AT AFRICA, OHIO | | | | | | | | | | | | | | |
| 67 | 257000. | 276000. | 280000. | 34. | 37. | 37. | 5.42 | 5.80 | 5.90 | 15.85 | 2.61 | 1 | 10 | 3 |
| 73 | 503000. | 480000. | 428000. | 44. | 42. | 37. | 10.58 | 10.08 | 9.00 | 24.13 | 2.61 | 1 | 10 | 3 |
| 3229000 ALUM CREEK AT COLUMBUS, OHIO | | | | | | | | | | | | | | |
| 63 | 151000. | 153000. | 125000. | 33. | 33. | 27. | 3.19 | 3.23 | 2.63 | 9.72 | 2.85 | 1 | 10 | 3 |
| 67 | 258000. | 277000. | 291000. | 37. | 40. | 42. | 5.43 | 5.83 | 6.11 | 14.73 | 2.85 | 1 | 10 | 3 |
| 73 | 502000. | 504000. | 455000. | 46. | 46. | 42. | 10.55 | 10.60 | 9.57 | 22.91 | 2.85 | 1 | 10 | 3 |
| 3229500 BIG WALNUT CREEK AT REES, OHIO | | | | | | | | | | | | | | |
| 63 | 155000. | 144000. | 121000. | 40. | 37. | 31. | 3.27 | 3.04 | 2.55 | 8.16 | 3.52 | 1 | 10 | 3 |
| 67 | 243000. | 242000. | 234000. | 38. | 38. | 36. | 5.11 | 5.10 | 4.92 | 13.49 | 3.52 | 1 | 10 | 3 |
| 73 | 434000. | 415000. | 422000. | 43. | 42. | 42. | 9.12 | 8.73 | 8.87 | 21.04 | 3.52 | 1 | 10 | 3 |
| 3230500 BIG DARBY CREEK AT DARBYVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 178000. | 156000. | 127000. | 44. | 38. | 31. | 3.76 | 3.29 | 2.68 | 8.56 | 3.51 | 1 | 10 | 3 |
| 67 | 298000. | 307000. | 246000. | 51. | 52. | 42. | 6.27 | 6.45 | 5.17 | 12.40 | 3.51 | 1 | 10 | 3 |
| 73 | 518000. | 523000. | 521000. | 53. | 53. | 53. | 10.89 | 11.00 | 10.95 | 20.63 | 3.51 | 1 | 10 | 3 |
| 3230800 DEER CREEK AT MOUNT STIRLING, OHIO | | | | | | | | | | | | | | |
| 67 | 351000. | 353000. | 290000. | 56. | 56. | 46. | 7.37 | 7.41 | 6.10 | 13.13 | 2.96 | 1 | 10 | 3 |
| 73 | 626000. | 625000. | 589000. | 57. | 57. | 54. | 13.16 | 13.13 | 12.39 | 23.15 | 2.96 | 1 | 10 | 3 |

TABLE 5-27 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3230900 DEER CREEK NEAR PANCOASTBURG, OHIO | | | | | | | | | | | | | | |
| 67 | 320000. | 318000. | 293000. | 52. | 51. | 47. | 6.73 | 6.69 | 6.16 | 13.06 | 3.08 | 1 | 13 | 3 |
| 73 | 511000. | 516000. | 442000. | 49. | 49. | 42. | 10.75 | 10.86 | 9.30 | 22.16 | 3.08 | 1 | 13 | 3 |
| 3231000 DEER CREEK AT WILLIAMSPORT, OHIO | | | | | | | | | | | | | | |
| 63 | 181000. | 173000. | 132000. | 37. | 35. | 27. | 3.81 | 3.64 | 2.79 | 10.34 | 3.20 | 1 | 10 | 3 |
| 67 | 321000. | 313000. | 291000. | 50. | 49. | 46. | 6.76 | 6.58 | 6.12 | 13.38 | 3.20 | 1 | 10 | 3 |
| 73 | 563000. | 560000. | 486000. | 51. | 51. | 44. | 11.84 | 11.78 | 10.22 | 23.00 | 3.20 | 1 | 10 | 3 |
| 3231500 SCIOTO RIVER AT CHILLICOTHE, OHIO | | | | | | | | | | | | | | |
| 63 | 209000. | 213000. | 214000. | 47. | 49. | 49. | 4.39 | 4.49 | 4.50 | 9.26 | 5.21 | 2 | 21 | 2 |
| 67 | 305000. | 299000. | 300000. | 48. | 47. | 47. | 6.42 | 6.29 | 6.31 | 13.43 | 5.21 | 2 | 21 | 2 |
| 73 | 570000. | 553000. | 565000. | 55. | 53. | 54. | 11.98 | 11.63 | 11.87 | 21.92 | 5.21 | 2 | 21 | 2 |
| 3232000 PAINT CREEK NEAR GREENFIELD, OHIO | | | | | | | | | | | | | | |
| 67 | 300000. | 306000. | 296000. | 50. | 51. | 49. | 6.31 | 6.44 | 6.24 | 12.67 | 3.01 | 2 | 10 | 4 |
| 73 | 586000. | 568000. | 539000. | 55. | 53. | 51. | 12.32 | 11.94 | 11.33 | 22.36 | 3.01 | 2 | 10 | 4 |
| 3232300 RATTLESNAKE CREEK NEAR CENTERFIELD, OHIO | | | | | | | | | | | | | | |
| 73 | 542000. | 549000. | 516000. | 53. | 54. | 51. | 11.39 | 11.55 | 10.84 | 21.31 | 2.91 | 2 | 13 | 4 |
| 3232470 PAINT CREEK NEAR BAINBRIDGE, OHIO | | | | | | | | | | | | | | |
| 73 | 548000. | 538000. | 513000. | 56. | 55. | 52. | 11.52 | 11.32 | 10.78 | 20.64 | 3.56 | 2 | 10 | 4 |

TABLE 5-27 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| **3232500 ROCKY FORK NEAR BARRETTS MILLS, OHIO** | | | | | | | | | | | | | | |
| 63 | 337000. | 370000. | 245000. | 54. | 59. | 39. | 7.09 | 7.79 | 5.16 | 13.18 | 2.69 | 2 | 90 | 4 |
| 67 | 347000. | 346000. | 310000. | 66. | 66. | 59. | 7.30 | 7.27 | 6.51 | 11.04 | 2.69 | 2 | 90 | 4 |
| 73 | 696000. | 710000. | 657000. | 63. | 64. | 59. | 14.63 | 14.93 | 13.80 | 23.32 | 2.69 | 2 | 90 | 4 |
| **3234000 PAINT CREEK NEAR BOURNEVILLE, OHIO** | | | | | | | | | | | | | | |
| 63 | 312000. | 290000. | 208000. | 48. | 45. | 32. | 6.56 | 6.11 | 4.37 | 13.68 | 3.81 | 2 | 21 | 3 |
| 67 | 314000. | 316000. | 307000. | 53. | 54. | 52. | 6.60 | 6.66 | 6.46 | 12.44 | 3.81 | 2 | 21 | 3 |
| 73 | 580000. | 563000. | 548000. | 60. | 58. | 56. | 12.18 | 11.83 | 11.52 | 20.46 | 3.81 | 2 | 21 | 3 |
| **3234500 SCIOTO RIVER AT HIGBY, OHIO** | | | | | | | | | | | | | | |
| 63 | 244000. | 228000. | 229000. | 51. | 47. | 47. | 5.14 | 4.81 | 4.81 | 10.17 | 5.52 | 3 | 21 | 2 |
| 67 | 323000. | 320000. | 321000. | 50. | 49. | 49. | 6.80 | 6.74 | 6.76 | 13.68 | 5.52 | 3 | 21 | 2 |
| 73 | 584000. | 569000. | 540000. | 57. | 55. | 52. | 12.28 | 11.95 | 12.15 | 21.62 | 5.52 | 3 | 21 | 2 |
| **3235500 TAR HOLLOW CREEK AT TAR HOLLOW STATE PARK, OHIO** | | | | | | | | | | | | | | |
| 63 | 257000. | 275000. | 232000. | 46. | 49. | 42. | 5.40 | 5.79 | 4.88 | 11.73 | 1.05 | 3 | 10 | 2 |
| 67 | 411000. | 396000. | 323000. | 58. | 56. | 46. | 8.64 | 8.33 | 6.80 | 14.82 | 1.05 | 3 | 10 | 2 |
| 73 | 600000. | 596000. | 508000. | 64. | 63. | 54. | 12.61 | 12.52 | 10.68 | 19.77 | 1.06 | 3 | 10 | 2 |
| **3237280 UPPER TWIN CREEK AT MCGAW, OHIO** | | | | | | | | | | | | | | |
| 67 | 406000. | 385000. | 314000. | 57. | 55. | 44. | 8.53 | 8.10 | 6.60 | 14.87 | 1.67 | 3 | 90 | 3 |
| 73 | 562000. | 578000. | 493000. | 65. | 67. | 57. | 11.81 | 12.14 | 10.36 | 18.15 | 1.65 | 3 | 90 | 3 |

SCIOTO BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 3223000 OLENTANGY RIVER AT CLARION, OHIO | | | | | | | | | | | | |
| FX | 32000. | 144000. | 101000. | 119000. | 77000. | 1920000. | 271000. | 81000. | 108000. | 19000. | 13000. | 2676. |
| SL | 35000. | 122000. | 96000. | 140000. | 80000. | 1507000. | 282000. | 78000. | 82000. | 22000. | 13000. | 2909. |
| LM | 38000. | 102000. | 86000. | 80000. | 59000. | 1240000. | 298000. | 75000. | 41000. | 14000. | 13000. | 2446. |
| 67 | | | | | | | | | | | | |
| FX | 18000. | 279000. | 492000. | 135000. | 321000. | 1054000. | 450000. | 874000. | 69000. | 23000. | 13000. | 11000. |
| SL | 18000. | 278000. | 764000. | 136000. | 351000. | 977000. | 415000. | 797000. | 67000. | 23000. | 13000. | 10000. |
| LM | 16000. | 111000. | 161000. | 142000. | 275000. | 869000. | 352000. | 901000. | 60000. | 24000. | 13000. | 8956. |
| 73 | | | | | | | | | | | | |
| FX | 342000. | 822000. | 789000. | 361000. | 344000. | 1064000. | 516000. | 311000. | 311000. | 239000. | 66000. | 25000. |
| SL | 363000. | 871000. | 794000. | 376000. | 342000. | 1018000. | 505000. | 331000. | 296000. | 205000. | 65000. | 25000. |
| LM | 234000. | 858000. | 682000. | 416000. | 296000. | 915000. | 478000. | 292000. | 293000. | 196000. | 46000. | 25000. |
| 67 3228305 ALUM CREEK AT AFRICA, OHIO | | | | | | | | | | | | |
| FX | 45000. | 272000. | 343000. | 128000. | 246000. | 1021000. | 345000. | 559000. | 67000. | 22000. | 15000. | 6939. |
| SL | 45000. | 335000. | 571000. | 129000. | 265000. | 981000. | 347000. | 518000. | 64000. | 19000. | 13000. | 6410. |
| LM | 44000. | 248000. | 870000. | 126000. | 221000. | 904000. | 301000. | 544000. | 55000. | 16000. | 13000. | 2458. |
| 73 | | | | | | | | | | | | |
| FX | 239000. | 814000. | 1035000. | 478000. | 379000. | 975000. | 752000. | 336000. | 524000. | 161000. | 272000. | 13000. |
| SL | 313000. | 951000. | 1020000. | 482000. | 397000. | 863000. | 713000. | 313000. | 385000. | 144000. | 157000. | 13000. |
| LM | 293000. | 862000. | 886000. | 480000. | 385000. | 654000. | 654000. | 292000. | 276000. | 120000. | 222000. | 13000. |
| 67 3230800DEER CREEK AT MOUNT STIRLING,O. | | | | | | | | | | | | |
| FX | 70000. | 408000. | 514000. | 161000. | 318000. | 1191000. | 468000. | 777000. | 158000. | 52000. | 52000. | 22000. |
| SL | 69000. | 412000. | 561000. | 162000. | 323000. | 1167000. | 475000. | 755000. | 157000. | 55000. | 57000. | 23000. |
| LM | 64000. | 157000. | 214000. | 172000. | 263000. | 1114000. | 439000. | 773000. | 161000. | 52000. | 33000. | 21000. |
| 73 | | | | | | | | | | | | |
| FX | 215000. | 973000. | 1046000. | 553000. | 484000. | 766000. | 1211000. | 414000. | 789000. | 666000. | 293000. | 107000. |
| SL | 245000. | 1086000. | 1067000. | 575000. | 481000. | 781000. | 1195000. | 409000. | 694000. | 585000. | 275000. | 107000. |
| LM | 200000. | 1036000. | 970000. | 595000. | 424000. | 673000. | 1218000. | 409000. | 539000. | 581000. | 318000. | 110000. |

TABLE 5-28. MONTHLY RECHARGE RATES FOR THE SCIOTO RIVER BASIN

Average gradient for major streams falls into several categories. Streams in the swampy headwaters have low gradients, such as the Little Scioto River (2.9 ft/mi.). From Marion County to Columbus, the gradients steepen to 5 to 7 feet per mile with rivers flowing in narrow gorges. When the Unglaciated Plateau is reached, the Scioto flows in a wide preglacial or interglacial valley with gradient averaging 1.7 feet per mile. Tributaries in this rough terrain have average gradients of 7 to 10 feet per mile.

Bedrock near the surface in the basin is Silurian limestone and dolomite to the west, Devonian limestone and shale in the central part, and Mississippian shale and sandstone in the east. Sandstones and some limestones with secondary permeability are generally good sources of water, while shales and dense limestones and dolomites are generally poor sources, both from the point of view of quantity and quality. Despite the fact that bedrock units store great quantities of water, the primary factor in base flow is the glacial material. Most of the area to the north is covered by till, which ranges from a thin veneer to as much as 250 feet thick. The till is a poor source of water, but end moraine deposits provide significant flow to the headwaters of the Scioto. Outwash deposits are the predominate source of base flow. These include kames and eskers, but are primarily sand and gravel valley fill in the major drainage. Major differences in stream flow can be seen when comparing upstream stations with those stations downstream from large outwash areas.

Well yields in the basin range from less than 5 to 1000 gpm or more. Typical areas of low yield are those of glacial till over dense shale. From 25 to 100 gpm can be obtained from fractured sandstone units, and 100 to 500 gpm from limestones in the western basin. High yields, often from 100 to 500 gpm and as high as 1000 gpm or more can be obtained from extensive sand and gravel deposits. Very high yields are found along perennial streams in the valley fill.

Annual precipitation in this region during 1963, 1967, and 1973 ranged from 25 to 35, 30 to 40, and 40 to 45 inches, respectively.

Highest flows are usually in the spring, but winter storms in November and December of 1972 greatly increased runoff for the water year 1973. Lowest flows occur in late summer and continue into fall. Sustained flow is quite high for streams flowing across valley aquifers.

Generally, streams in the northern part of the basin have lower sustained flows than those in the southern part. The bedrock in the upper half of the basin contributes negligible amounts to streamflow and the glacial materials are primarily impervious tills (Cross & Hedges, 1959).

The 90-percent flow for upstream station on the Olentangy River, Alum and Deer Creeks during 1967 was 0.022, 0.016, and 0.061 cfs/sq. mi., respectively (Table 5-26).

Separation of hydrographs shows a range of recharge rates from a low of 89,000 gpd/sq. mi. during a very dry year on Mill Creek, to 657,000 gpd/sq. mi. during the very wet year of 1973 in Rocky Fork (Table 5-27). Most recharge rates for the normal precipitation year range from 200,000 to 300,000 gpd/sq. mi. in the northern streams and 300,000 to 400,000 gpd/sq. mi. for the southern streams. Recharge rates in the areas not immediately adjoining the streams is estimated to be between 100,000 and 200,000 gpd/sq. mi. and are based on low-flow measurements and a few upstream stations in the glaciated till plains. Recharge rates in the unglaciated southern section of the basin have also been estimated to be between 100,000 and 200,000 gpd/sq. mi., based on data from adjoining basins.

The chemical quality of ground water in the zone of intensive movement is consistently hard in most sand and gravel aquifers, but varies widely even between wells of the same depth and less than a mile apart. Hardness ranges from a low of 100 to as high as 500 mg/l; many of the analyses range from 200 to 400 mg/l. Dissolved solids are moderate with a range of 120 to 700 with most analyses falling between 300 and 600 mg/l. Iron is a problem in most areas of the outwash. Where iron is present, it occurs in amounts from 1 to 16 mg/l, but in most cases it ranges from 2 to 3 mg/l. Chloride is very low, except where induced infiltration from streams below municipalities causes it to exceed 100 mg/l. Most natural ground water in this basin has less than 20 mg/l of chloride. Some variation in near-surface ground-water quality may be due to upward leakage from bedrock aquifers into the more permeable glacial aquifers. Some of the wide variation in quality from adjacent wells could be caused by upward flowing recharge, possibly a zone of fractures, contributing a major component from the bedrock. This is an area of recharge that deserves further work.

### Whiteoak Creek, Little Miami River and Mill Creek Basins

Lying adjacent to the Ohio River in southwestern Ohio are several relatively small streams that include Ohio Brush, Eagle and Whiteoak Creeks. To the immediate west is the Little Miami River and in the extreme southwest, draining much of the Greater Cincinnati area, is Mill Creek (Fig. 5-13). Whiteoak, Eagle and Ohio Brush Creeks flow southward into the Ohio River and drain a combined region of 982 sq. mi., of which Ohio Brush (435 sq. mi.) is the largest.

Limestones of Silurian age covers most of Ohio Brush Creek basin, but the main stream and nearly all of its tributaries have cut through the limestone and flow across an Upper Ordovician sequence of alternating thin layers of limestone and shale. Eagle and Whiteoak Creek drainages are underlain also by thin layers of shale and limestone of Upper Ordovician age but these rocks are overlain by generally thin and commonly patchy deposits of glacial drift.

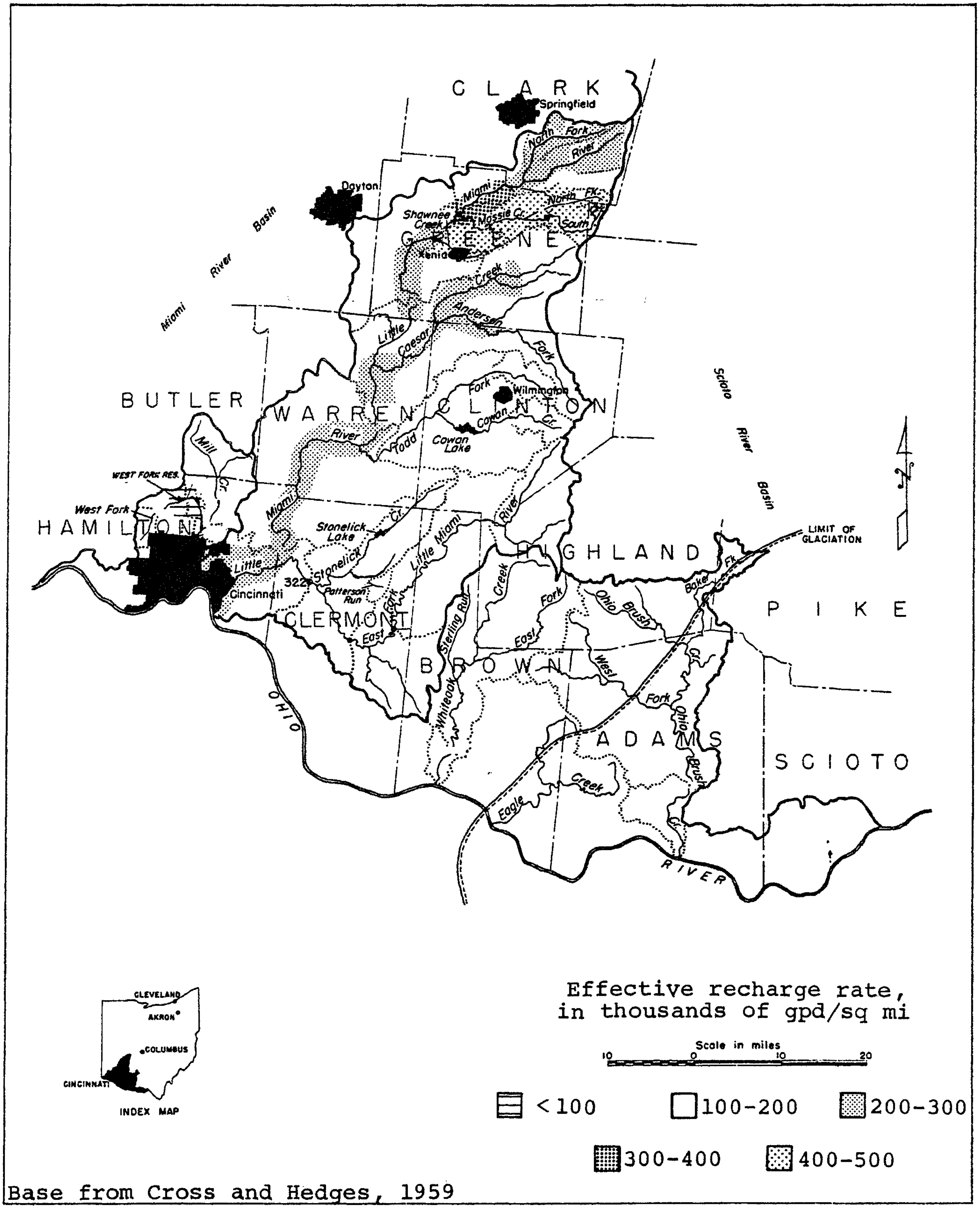



FIGURE 5-13. EFFECTIVE RECHARGE RATES, OHIO RIVER DRAINAGE BETWEEN THE SCIOTO AND MIAMI RIVER BASINS

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3237500 OHIO BRUSH CREEK NEAR WEST UNION, OHIO | | | | | | | | | | | | | | |
| 63 | 137000. | 141000. | 127000. | 22. | 23. | 21. | 2.89 | 2.97 | 2.68 | 13.01 | 3.29 | 3 | 90 | 3 |
| 67 | 198000. | 198000. | 198000. | 30. | 30. | 30. | 4.17 | 4.16 | 4.18 | 13.78 | 3.29 | 3 | 90 | 3 |
| 73 | 341000. | 338000. | 323000. | 34. | 33. | 32. | 7.16 | 7.10 | 6.80 | 21.34 | 3.29 | 3 | 90 | 3 |
| 3238500 WHITEOAK CREEK NEAR GEORGETOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 109000. | 129000. | 132000. | 18. | 21. | 22. | 2.31 | 2.71 | 2.78 | 12.65 | 2.95 | 3 | 10 | 5 |
| 67 | 165000. | 165000. | 160000. | 30. | 31. | 30. | 3.47 | 3.48 | 3.38 | 11.37 | 2.95 | 3 | 10 | 5 |
| 73 | 331000. | 326000. | 297000. | 25. | 25. | 22. | 6.96 | 6.86 | 6.25 | 27.77 | 2.94 | 3 | 10 | 5 |
| 3240000 LITTLE MIAMI RIVER NEAR OLDTOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 291000. | 296000. | 268000. | 52. | 53. | 48. | 6.11 | 6.24 | 5.65 | 11.78 | 2.64 | 2 | 13 | 5 |
| 67 | 430000. | 434000. | 395000. | 66. | 67. | 61. | 9.04 | 9.14 | 8.31 | 13.71 | 2.64 | 2 | 13 | 5 |
| 73 | 670000. | 674000. | 671000. | 67. | 68. | 68. | 14.09 | 14.16 | 14.11 | 20.90 | 2.64 | 2 | 13 | 5 |
| 3240500 NORTH FORK MASSIES CREEK AT CEDARVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 337000. | 353000. | 296000. | 57. | 60. | 50. | 7.09 | 7.42 | 6.22 | 12.35 | 1.96 | 2 | 13 | 5 |
| 67 | 558000. | 551000. | 455000. | 76. | 75. | 62. | 11.73 | 11.58 | 9.57 | 15.34 | 1.96 | 2 | 13 | 5 |
| 3241000 SOUTH FORK MASSIES CREEK NEAR CEDARVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 366000. | 360000. | 277000. | 51. | 50. | 39. | 7.69 | 7.57 | 5.83 | 15.02 | 1.76 | 2 | 13 | 5 |
| 67 | 538000. | 523000. | 416000. | 67. | 66. | 52. | 11.30 | 11.10 | 8.74 | 16.77 | 1.76 | 2 | 13 | 5 |

TABLE 5-29. RECHARGE STATISTICS BETWEEN SCIOTO AND MIAMI BASINS

TABLE 5-29 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3241500 MASSIES CREEK AT WILBERFORCE, OHIO | | | | | | | | | | | | | | |
| 63 | 253000. | 262000. | 196000. | 41. | 42. | 32. | 5.32 | 5.52 | 4.13 | 13.10 | 2.29 | 2 | 13 | 5 |
| 67 | 463000. | 471000. | 406000. | 62. | 63. | 54. | 9.74 | 9.91 | 8.55 | 15.77 | 2.29 | 2 | 13 | 5 |
| 73 | 695000. | 707000. | 692000. | 60. | 61. | 60. | 14.60 | 14.85 | 14.55 | 24.21 | 2.29 | 2 | 13 | 5 |
| 3242050 LITTLE MIAMI RIVER NEAR SPRING VALLEY, OHIO | | | | | | | | | | | | | | |
| 73 | 699000. | 695000. | 677000. | 63. | 63. | 61. | 14.68 | 14.61 | 14.23 | 23.33 | 3.26 | 2 | 21 | 5 |
| 3242150 CAESAR CREEK NEAR XENIA, OHIO | | | | | | | | | | | | | | |
| 73 | 483000. | 475000. | 461000. | 48. | 47. | 46. | 10.17 | 9.99 | 9.70 | 21.15 | 2.35 | 2 | 12 | 5 |
| 3242200 ANDERSON FORK NEAR NEW BURLINGTON, OHIO | | | | | | | | | | | | | | |
| 73 | 470000. | 475000. | 450000. | 47. | 47. | 45. | 9.88 | 9.99 | 9.46 | 21.11 | 2.39 | 2 | 13 | 5 |
| 3242300 CAESAR CREEK AT HARVEYSBURG,OHIO | | | | | | | | | | | | | | |
| 63 | 185000. | 211000. | 180000. | 36. | 41. | 35. | 3.89 | 4.45 | 3.78 | 10.88 | 2.91 | 2 | 13 | 5 |
| 67 | 323000. | 327000. | 279000. | 50. | 50. | 43. | 6.80 | 6.89 | 5.88 | 13.65 | 2.91 | 2 | 13 | 5 |
| 73 | 556000. | 550000. | 529000. | 50. | 50. | 48. | 11.69 | 11.57 | 11.13 | 23.32 | 2.91 | 2 | 13 | 5 |
| 3242350 CAESAR CREEK NEAR WELLMAN, OHIO | | | | | | | | | | | | | | |
| 67 | 327000. | 326000. | 272000. | 48. | 48. | 40. | 6.87 | 6.85 | 5.72 | 14.37 | 2.99 | 2 | 21 | 5 |
| 73 | 534000. | 537000. | 517000. | 52. | 52. | 50. | 11.23 | 11.28 | 10.87 | 21.63 | 2.99 | 2 | 21 | 5 |
| 3244000 TODD FORK NEAR ROACHESTER, OHIO | | | | | | | | | | | | | | |
| 63 | 183000. | 212000. | 186000. | 31. | 36. | 32. | 3.86 | 4.47 | 3.91 | 12.41 | 2.94 | 2 | 21 | 5 |
| 67 | 231000. | 231000. | 192000. | 41. | 41. | 34. | 4.87 | 4.85 | 4.04 | 11.73 | 2.94 | 2 | 21 | 5 |
| 73 | 474000. | 480000. | 457000. | 42. | 43. | 41. | 9.98 | 10.09 | 9.60 | 23.61 | 2.94 | 2 | 21 | 5 |

TABLE 5-29 CONTINUED

| YR | RECHARGE RATE, GPD/SQ.MI. FIXED | SLIDING | LOCMIN | GW, PERCENT FX | SL | LM | GW, IN INCHES FX | SL | LM | DIS IN | N DAYS | GEOLOGY REL | SUR | BRK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3245500 LITTLE MIAMI RIVER AT MILFORD, OHIO | | | | | | | | | | | | | | |
| 63 | 221000. | 212000. | 213000. | 39. | 37. | 38. | 4.65 | 4.46 | 4.47 | 11.90 | 4.13 | 2 | 21 | 5 |
| 67 | 277000. | 292000. | 294000. | 44. | 46. | 46. | 5.84 | 6.15 | 6.19 | 13.39 | 4.13 | 2 | 21 | 5 |
| 73 | 568000. | 580000. | 582000. | 45. | 46. | 46. | 11.94 | 12.19 | 12.23 | 26.56 | 4.13 | 2 | 21 | 5 |
| 3246200 EAST FORK LITTLE MIAMI RIVER NEAR MARATHON, OHIO | | | | | | | | | | | | | | |
| 73 | 339000. | 338000. | 311000. | 28. | 28. | 26. | 7.14 | 7.11 | 6.55 | 25.25 | 2.87 | 2 | 10 | 5 |
| 3246500 EAST FORK LITTLE MIAMI RIVER AT WILLIAMSBURG, OHIO 19 | | | | | | | | | | | | | | |
| 63 | 129000. | 145000. | 130000. | 21. | 23. | 21. | 2.72 | 3.05 | 2.75 | 13.08 | 2.99 | 2 | 10 | 5 |
| 67 | 159000. | 161000. | 130000. | 32. | 33. | 26. | 3.35 | 3.39 | 2.74 | 10.42 | 2.99 | 2 | 10 | 5 |
| 73 | 336000. | 340000. | 315000. | 27. | 27. | 25. | 7.08 | 7.14 | 6.63 | 26.61 | 2.99 | 2 | 10 | 5 |
| 3247050 EAST FORK LITTLE MIAMI RIVER NEAR BATAVIA, OHIO | | | | | | | | | | | | | | |
| 67 | 159000. | 142000. | 102000. | 31. | 27. | 20. | 3.35 | 2.99 | 2.14 | 10.95 | 3.24 | 2 | 10 | 5 |
| 73 | 323000. | 320000. | 400000. | 26. | 26. | 32. | 6.80 | 6.73 | 8.41 | 26.12 | 3.23 | 2 | 10 | 5 |
| 3247400 SHAYLER RUN NEAR PERINTOWN, OHIO | | | | | | | | | | | | | | |
| 73 | 595000. | 620000. | 504000. | 45. | 47. | 38. | 12.50 | 13.03 | 10.60 | 27.83 | 1.64 | 2 | 21 | 5 |
| 3247500 EAST FORK LITTLE MIAMI RIVER AT PERINTOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 119000. | 123000. | 109000. | 20. | 21. | 18. | 2.50 | 2.59 | 2.30 | 12.48 | 3.43 | 2 | 21 | 5 |
| 67 | 153000. | 146000. | 146000. | 32. | 30. | 30. | 3.22 | 3.08 | 3.08 | 10.20 | 3.43 | 2 | 21 | 5 |
| 73 | 314000. | 310000. | 291000. | 26. | 26. | 24. | 6.60 | 6.52 | 6.12 | 25.06 | 3.43 | 2 | 21 | 5 |

TABLE 5-29 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3248000 LITTLE MIAMI RIVER AT PLAINVILLE, OHIO | | | | | | | | | | | | | | |
| 67 | 235000. | 250000. | 251000. | 41. | 44. | 44. | 4.94 | 5.27 | 5.29 | 11.92 | 4.43 | 2 | 10 | 5 |
| 3255500 MILL CREEK AT READING, OHIO | | | | | | | | | | | | | | |
| 63 | 115000. | 124000. | 130000. | 25. | 28. | 29. | 2.43 | 2.62 | 2.75 | 9.52 | 2.36 | 2 | 22 | 5 |
| 67 | 204000. | 200000. | 188000. | 41. | 40. | 38. | 4.30 | 4.22 | 3.96 | 10.51 | 2.36 | 2 | 22 | 5 |
| 73 | 407000. | 414000. | 394000. | 37. | 37. | 35. | 8.56 | 8.71 | 8.28 | 23.36 | 2.36 | 2 | 22 | 5 |
| 3257500 WEST FORK MILL CREEK AT WOODLAWN, OHIO | | | | | | | | | | | | | | |
| 63 | 72000. | 87000. | 92000. | 14. | 16. | 17. | 1.53 | 1.84 | 1.94 | 11.17 | 2.00 | 2 | 22 | 5 |
| 67 | 106000. | 120000. | 98000. | 21. | 24. | 19. | 2.23 | 2.53 | 2.06 | 10.70 | 2.00 | 2 | 22 | 5 |
| 73 | 240000. | 265000. | 204000. | 23. | 25. | 19. | 5.05 | 5.57 | 4.29 | 22.05 | 2.00 | 2 | 22 | 5 |
| 3259000 MILL CREEK AT CARTHAGE, OHIO | | | | | | | | | | | | | | |
| 63 | 109000. | 140000. | 100000. | 24. | 31. | 22. | 2.29 | 2.95 | 2.12 | 9.64 | 2.58 | 2 | 22 | 5 |
| 67 | 187000. | 190000. | 178000. | 37. | 37. | 35. | 3.95 | 4.00 | 3.76 | 10.73 | 2.58 | 2 | 22 | 5 |
| 73 | 330000. | 352000. | 339000. | 31. | 33. | 32. | 6.94 | 7.40 | 7.14 | 22.11 | 2.58 | 2 | 22 | 5 |

LITTLE MIAMI BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 3237500 OHIO BRUSH CREEK NEAR WEST UNION, OHIO | | | | | | | | | | | | |
| FX | 6490. | 78000. | 96000. | 120000. | 174000. | 716000. | 179000. | 183000. | 56000. | 16000. | 11000. | 3391. |
| SL | 7175. | 80000. | 106000. | 124000. | 185000. | 744000. | 185000. | 171000. | 54000. | 17000. | 12900. | 3833. |
| LM | 7004. | 55000. | 92900. | 115000. | 162000. | 683000. | 199000. | 177000. | 58000. | 12800. | 9574. | 4353. |
| 67 | | | | | | | | | | | | |
| FX | 7310. | 96000. | 229000. | 135000. | 221000. | 843000. | 328000. | 454000. | 40000. | 11000. | 4392. | 3962. |
| SL | 7816. | 93000. | 317000. | 132000. | 218000. | 814000. | 316000. | 408000. | 41000. | 10600. | 5062. | 903. |
| LM | 5416. | 85000. | 146000. | 144000. | 223000. | 1009000. | 308000. | 384000. | 56000. | 10000. | 2610. | 902. |
| 73 | | | | | | | | | | | | |
| FX | 56000. | 408000. | 797000. | 314000. | 360000. | 386000. | 819000. | 453000. | 241000. | 189000. | 54000. | 16000. |
| SL | 52000. | 452000. | 787000. | 296000. | 359000. | 385000. | 921000. | 405000. | 194000. | 135000. | 62000. | 16900. |
| LM | 64000. | 456000. | 792000. | 280000. | 316000. | 381000. | 805000. | 377000. | 238000. | 98000. | 49000. | 27900. |
| 67 3238500 WHITEOAK CREEK NEAR GEORGETOWN, OHIO | | | | | | | | | | | | |
| FX | 10000. | 65000. | 221000. | 89000. | 171000. | 766000. | 194000. | 394000. | 28900. | 15900. | 10000. | 2589. |
| SL | 9494. | 70000. | 325000. | 89000. | 177000. | 721000. | 198000. | 320000. | 28000. | 18000. | 14000. | 2360. |
| LM | 9834. | 53000. | 431000. | 91000. | 158000. | 714000. | 176000. | 231000. | 28000. | 11000. | 5526. | 2657. |
| 73 | | | | | | | | | | | | |
| FX | 85000. | 423000. | 770000. | 251000. | 226000. | 442000. | 1003000. | 265000. | 228000. | 179000. | 62000. | 35200. |
| SL | 86000. | 507000. | 680000. | 286000. | 253000. | 462000. | 837000. | 293000. | 230000. | 171000. | 77000. | 31000. |
| LM | 84000. | 434000. | 544000. | 322000. | 220000. | 373000. | 859000. | 255000. | 221000. | 167000. | 62000. | 25800. |
| 63 3241000 SOUTH FORK MASSIES CREEK NEAR CEDARVILLE | | | | | | | | | | | | |
| FX | 23000. | 183000. | 167000. | 395000. | 234000. | 1803000. | 738000. | 354000. | 107000. | 100000. | 200000. | 41000. |
| SL | 22000. | 203000. | 169000. | 340000. | 272000. | 1778000. | 690000. | 355000. | 108000. | 103000. | 215000. | 41000. |
| LM | 23000. | 129000. | 148000. | 208000. | 221000. | 1161000. | 652000. | 370000. | 105000. | 91000. | 161000. | 46000. |
| 67 | | | | | | | | | | | | |
| FX | 72000. | 550000. | 995000. | 210000. | 404000. | 1649000. | 840000. | 1395000. | 217000. | 57000. | 33000. | 1449. |
| SL | 71000. | 587000. | 937000. | 217000. | 453000. | 1603000. | 773000. | 1356000. | 218000. | 61000. | 33000. | 2933. |
| LM | 69000. | 143000. | 834000. | 210000. | 310000. | 1237000. | 527000. | 1319000. | 212000. | 58000. | 31000. | 923. |

TABLE 5-30. MONTHLY RECHARGE RATES BETWEEN SCIOTO AND MIAMI RIVER BASINS

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3237500 OHIO BRUSH CREEK NEAR WEST UNION, OHIO | | | | | | | | | |
| 63 | 12.38595 | 4.19415 | 0.00672 | 0.01098 | 0.02842 | 0.10853 | 0.19380 | 0 | 0 |
| 67 | 19.11092 | 5.28004 | 0.00212 | 0.00568 | 0.02558 | 0.14212 | 0.25452 | 0 | 0 |
| 73 | 8.41021 | 2.62646 | 0.03876 | 0.05297 | 0.22868 | 0.47287 | 0.74419 | 0 | 0 |
| 3238500 WHITEOAK CREEK NEAR GEORGETOWN, OHIO | | | | | | | | | |
| 63 | 14.22439 | 3.43303 | 0.00360 | 0.00676 | 0.02523 | 0.06757 | 0.09910 | 0 | 0 |
| 67 | 14.64581 | 4.73327 | 0.00495 | 0.00901 | 0.02342 | 0.08108 | 0.14640 | 0 | 0 |
| 73 | 8.09321 | 2.61849 | 0.05963 | 0.09174 | 0.24771 | 0.43119 | 0.61468 | 0 | 0 |
| 3240000 LITTLE MIAMI RIVER NEAR OLDTOWN, OHIO | | | | | | | | | |
| 63 | 3.07409 | 1.83225 | 0.13178 | 0.15504 | 0.21705 | 0.29457 | 0.34884 | 0 | 0 |
| 67 | 3.97360 | 2.19908 | 0.10078 | 0.14729 | 0.24806 | 0.42636 | 0.52713 | 0 | 0 |
| 73 | 3.06372 | 1.59466 | 0.29457 | 0.34109 | 0.76744 | 0.94574 | 1.19380 | 0 | 0 |
| 3240500 NORTH FORK MASSIES CREEK AT CEDARVILLE, OHIO | | | | | | | | | |
| 63 | 5.16398 | 2.40081 | 0.05190 | 0.07266 | 0.12457 | 0.24221 | 0.29066 | 0 | 0 |
| 67 | 7.22409 | 3.03239 | 0.04152 | 0.05536 | 0.15052 | 0.38062 | 0.65744 | 0 | 0 |
| 3241000 SOUTH FORK MASSIES CREEK NEAR CEDARVILLE, OHIO | | | | | | | | | |
| 63 | 7.07107 | 2.40613 | 0.03509 | 0.04094 | 0.11111 | 0.25731 | 0.33626 | 0 | 0 |
| 67 | 15.74802 | 3.30470 | 0.00234 | 0.01462 | 0.11111 | 0.26901 | 0.45906 | 0 | 0 |

TABLE 5-31. FLOW-RATIO STATISTICS BETWEEN SCIOTO AND MIAMI RIVER BASINS

TABLE 5-31 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3241500 MASSIES CREEK AT WILBERFORCE, OHIO | | | | | | | | | |
| 63 | 4.10188 | 2.18899 | 0.06487 | 0.09968 | 0.15190 | 0.25316 | 0.33228 | 0 | 3 |
| 67 | 7.07107 | 2.66145 | 0.04589 | 0.06013 | 0.18987 | 0.36392 | 0.56962 | 0 | 0 |
| 73 | 3.45033 | 1.96141 | 0.18987 | 0.33228 | 0.62104 | 0.88608 | 1.21835 | 0 | 0 |
| 3242050 LITTLE MIAMI RIVER NEAR SPRING VALLEY, OHIO | | | | | | | | | |
| 73 | 2.75241 | 1.61497 | 0.38525 | 0.45082 | 0.82445 | 1.03825 | 1.33333 | 0 | 0 |
| 3242150 CAESAR CREEK NEAR XENIA, OHIO | | | | | | | | | |
| 73 | 4.60977 | 2.19427 | 0.12745 | 0.16807 | 0.37815 | 0.58824 | 0.82633 | 0 | 0 |
| 3242200 ANDERSON FORK NEAR NEW BURLINGTON, OHIO | | | | | | | | | |
| 73 | 6.16655 | 2.52380 | 0.07455 | 0.09769 | 0.29563 | 0.59126 | 0.86118 | 0 | 0 |
| 3242300 CAESAR CREEK AT HARVEYSBURG,OHIO | | | | | | | | | |
| 63 | 8.30949 | 2.71746 | 0.01148 | 0.02010 | 0.06220 | 0.11962 | 0.19139 | 0 | 0 |
| 67 | 12.89233 | 4.47493 | 0.00670 | 0.01579 | 0.04785 | 0.17703 | 0.32057 | 0 | 0 |
| 73 | 4.66575 | 2.34726 | 0.11962 | 0.18660 | 0.37321 | 0.66507 | 0.99282 | 0 | 0 |
| 3242350 CAESAR CREEK NEAR WELLMAN, OHIO | | | | | | | | | |
| 67 | 16.37523 | 4.79583 | 0.00795 | 0.01130 | 0.04184 | 0.18410 | 0.29289 | 0 | 0 |
| 73 | 4.90166 | 2.31249 | 0.10460 | 0.15900 | 0.39121 | 0.62762 | 0.90167 | 0 | 0 |
| 3244000 TODD FORK NEAR ROACHESTER, OHIO | | | | | | | | | |
| 63 | 8.54536 | 3.03764 | 0.01005 | 0.01963 | 0.05023 | 0.12329 | 0.17808 | 0 | 0 |
| 67 | 16.97749 | 4.72280 | 0.00292 | 0.00776 | 0.03071 | 0.09132 | 0.15068 | 0 | 0 |
| 73 | 7.00386 | 2.47223 | 0.05023 | 0.08447 | 0.31621 | 0.57078 | 0.87443 | 0 | 0 |

TABLE 5-31 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3245500 LITTLE MIAMI RIVER AT MILFORD, OHIO | | | | | | | | | |
| 63 | 4.29888 | 1.93313 | 0.06899 | 0.08479 | 0.14381 | 0.23774 | 0.28263 | 0 | 0 |
| 67 | 5.29760 | 2.55006 | 0.07564 | 0.09019 | 0.14796 | 0.31255 | 0.40565 | 0 | 0 |
| 73 | 4.11393 | 2.01027 | 0.18953 | 0.24190 | 0.57544 | 0.96426 | 1.24688 | 0 | 0 |
| 3246200 EAST FORK LITTLE MIAMI RIVER NEAR MARATHON, OHIO | | | | | | | | | |
| 73 | 7.26382 | 2.60276 | 0.04051 | 0.09744 | 0.25000 | 0.46667 | 0.70256 | 0 | 0 |
| 3246500 EAST FORK LITTLE MIAMI RIVER AT WILLIAMSBURG, OHIO | | | | | | | | | |
| 63 | 10.57233 | 3.38225 | 0.00675 | 0.01308 | 0.04103 | 0.09705 | 0.13291 | 0 | 0 |
| 67 | 22.18059 | 4.78834 | 0.00114 | 0.00395 | 0.01909 | 0.08017 | 0.14346 | 0 | 0 |
| 73 | 7.69859 | 2.73990 | 0.03924 | 0.08650 | 0.22468 | 0.45570 | 0.67722 | 0 | 0 |
| 3247050 EAST FORK LITTLE MIAMI RIVER NEAR BATAVIA, OHIO | | | | | | | | | |
| 67 | 19.79057 | 4.26830 | 0.00081 | 0.00501 | 0.02423 | 0.08635 | 0.15181 | 0 | 0 |
| 73 | 7.49713 | 2.57415 | 0.03693 | 0.08239 | 0.28125 | 0.55398 | 0.79687 | 0 | 0 |
| 3247400 SHAYLER RUN NEAR PERINTOWN, OHIO | | | | | | | | | |
| 73 | 5.65685 | 2.68995 | 0.13559 | 0.16949 | 0.33898 | 0.64407 | 0.93220 | 0 | 0 |
| 3247500 EAST FORK LITTLE MIAMI RIVER AT PERINTOWN, OHIO | | | | | | | | | |
| 63 | 8.76379 | 2.72822 | 0.01261 | 0.02038 | 0.04622 | 0.08824 | 0.12185 | 0 | 0 |
| 67 | 15.37300 | 4.15278 | 0.00504 | 0.00830 | 0.02994 | 0.07773 | 0.16176 | 0 | 0 |
| 73 | 7.29766 | 2.48107 | 0.06303 | 0.09034 | 0.30357 | 0.53992 | 0.76366 | 0 | 0 |

TABLE 5-31 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3248000 LITTLE MIAMI RIVER AT PLAINVILLE, OHIO | | | | | | | | | |
| 67 | 5.63718 | 2.48581 | 0.06421 | 0.07881 | 0.12376 | 0.25102 | 0.32983 | 0 | 0 |
| 3255500 MILL CREEK AT READING, OHIO | | | | | | | | | |
| 63 | 3.37209 | 1.73963 | 0.07671 | 0.08493 | 0.10411 | 0.11918 | 0.13425 | 0 | 0 |
| 67 | 3.86425 | 2.04495 | 0.08356 | 0.10137 | 0.15068 | 0.21918 | 0.30137 | 0 | 0 |
| 73 | 4.34813 | 2.02405 | 0.17808 | 0.21918 | 0.42466 | 0.63014 | 0.79452 | 0 | 0 |
| 3257500 WEST FORK MILL CREEK AT WOODLAWN, OHIO | | | | | | | | | |
| 63 | 33.43669 | 4.47214 | 0.0 | 0.00100 | 0.01863 | 0.07453 | 0.09317 | 0 | 43 |
| 67 | 25.49509 | 5.34522 | 0.0 | 0.00248 | 0.01957 | 0.07764 | 0.15217 | 0 | 19 |
| 73 | 13.10216 | 2.45450 | 0.01646 | 0.02795 | 0.18944 | 0.43478 | 0.55901 | 0 | 0 |
| 3259000 MILL CREEK AT CARTHAGE, OHIO | | | | | | | | | |
| 63 | 3.90969 | 2.09596 | 0.05565 | 0.06087 | 0.07522 | 0.09565 | 0.13043 | 0 | 0 |
| 67 | 4.54459 | 2.26779 | 0.07043 | 0.08652 | 0.12174 | 0.21739 | 0.27826 | 0 | 0 |
| 73 | 5.75018 | 2.06621 | 0.11304 | 0.13478 | 0.33913 | 0.54783 | 0.72174 | 0 | 0 |

Most of the ground-water supplies in this region are obtained from wells in alluvium, in sandy layers in the till and from fracture and solution openings in limestone. Yields are generally small and in the order of only a few gallons per minute.

The basin slopes southward toward the Ohio River. Relief is moderate to high, especially along the breaks of the Ohio River.

Annual precipitation on Ohio Brush - Eagle - Whiteoak Creek basin ranged from about 36 to 42 inches in 1963, slightly more than 35 inches in 1967 and from about 42 to 52 inches in 1973.

Effective ground-water recharge rates in this area are shown in Table 5-29. They ranged from a low of about 127,000 gpd/sq. mi. in 1963 to a high of 323,000 in Ohio Brush Creek in 1973. During a year of normal precipitation ground-water runoff accounts for about 30 percent of the total runoff.

Monthly recharge rates ranged from a low of about 9000 gpd/sq. mi. in September 1967 in Ohio Brush to a maximum of 859,000 in Whiteoak Creek in April 1973 (Table 5-30). Flow ratios are quite low (Table 5-31).

## Miami River Basin

Draining southeastern Ohio, the wide valley of the Miami River flows through the Glaciated Till Plains, breaking the gently rolling plains (Fig. 5-14). The topography becomes more rugged southward, but the relief is not as great as it is in other parts of southeastern Ohio. The Miami is 170 miles long and drains 5385 square miles. Major tributaries include Loramie Creek (269 sq. mi.), Stillwater River (673 sq. mi.), Mad River (656 sq. mi.), Twin Creek (315 sq. mi.), Talawanda (Fourmile) Creek (322 sq. mi.), and Whitewater River (1483 sq. mi.), among others.

All of the major tributaries, except the Mad River, enter the mainstem from

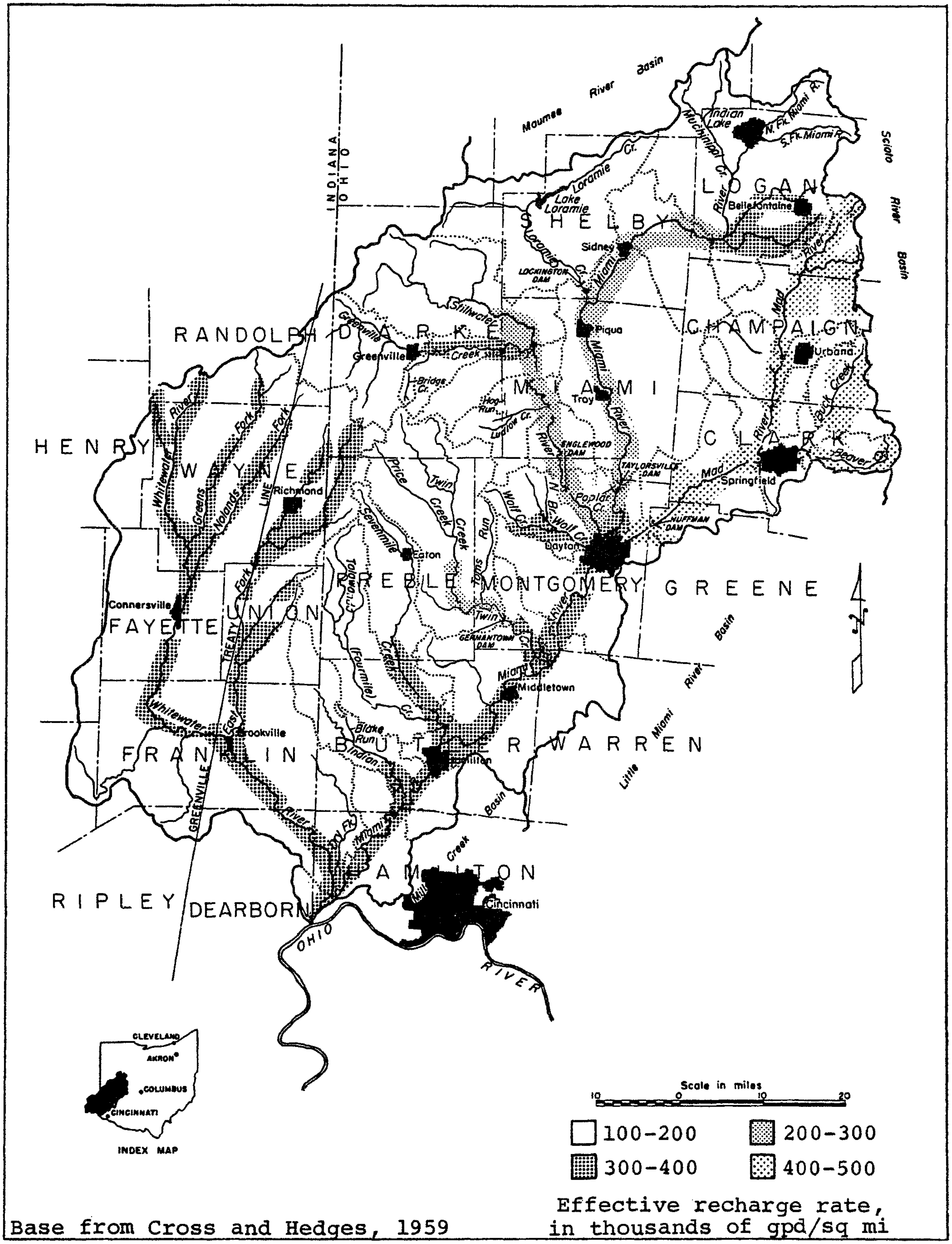



FIGURE 5-14. EFFECTIVE RECHARGE RATES IN THE MIAMI RIVER BASIN

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3260700 BOKENGEHALAS CREEK NEAR DEGRAFF, OHIO | | | | | | | | | | | | | | |
| 63 | 247000. | 244000. | 229000. | 57. | 57. | 53. | 5.20 | 5.14 | 4.82 | 9.09 | 2.05 | 2 | 12 | 4 |
| 67 | 420000. | 428000. | 392000. | 64. | 65. | 60. | 8.82 | 9.00 | 8.25 | 13.86 | 2.05 | 2 | 12 | 4 |
| 73 | 727000. | 715000. | 681000. | 69. | 68. | 65. | 15.27 | 15.02 | 14.31 | 22.17 | 2.05 | 2 | 12 | 4 |
| 3260800 STONY CREEK NEAR DEGRAFF, OHIO | | | | | | | | | | | | | | |
| 63 | 218000. | 216000. | 189000. | 53. | 53. | 46. | 4.59 | 4.55 | 3.99 | 8.66 | 2.26 | 2 | 12 | 4 |
| 67 | 341000. | 340000. | 326000. | 66. | 65. | 63. | 7.17 | 7.16 | 6.86 | 10.94 | 2.26 | 2 | 12 | 4 |
| 73 | 719000. | 697000. | 655000. | 65. | 63. | 59. | 15.12 | 14.65 | 13.76 | 23.25 | 2.26 | 2 | 12 | 4 |
| 3261500 GREAT MIAMI RIVER AT SIDNEY, OHIO | | | | | | | | | | | | | | |
| 63 | 221000. | 194000. | 146000. | 58. | 51. | 39. | 4.65 | 4.08 | 3.08 | 7.98 | 3.52 | 2 | 12 | 4 |
| 67 | 308000. | 314000. | 252000. | 49. | 50. | 40. | 6.47 | 6.60 | 5.31 | 13.22 | 3.52 | 2 | 12 | 4 |
| 73 | 631000. | 609000. | 583000. | 54. | 52. | 50. | 13.27 | 12.81 | 12.25 | 24.43 | 3.52 | 2 | 12 | 4 |
| 3261950 LORAMIE CREEK NEAR NEWPORT, OHIO | | | | | | | | | | | | | | |
| 67 | 262000. | 277000. | 209000. | 39. | 41. | 31. | 5.52 | 5.84 | 4.40 | 14.10 | 2.73 | 2 | 13 | 4 |
| 73 | 435000. | 413000. | 351000. | 41. | 39. | 33. | 9.15 | 8.69 | 7.39 | 22.51 | 2.73 | 2 | 13 | 4 |
| 3262000 LORAMIE CREEK AT LOCKINGTON, OHIO | | | | | | | | | | | | | | |
| 63 | 127000. | 111000. | 68000. | 39. | 34. | 21. | 2.68 | 2.34 | 1.45 | 6.81 | 3.03 | 2 | 12 | 4 |
| 67 | 178000. | 198000. | 161000. | 30. | 33. | 27. | 3.74 | 4.18 | 3.40 | 12.66 | 3.03 | 2 | 12 | 4 |
| 73 | 367000. | 370000. | 340000. | 35. | 36. | 33. | 7.72 | 7.78 | 7.16 | 21.79 | 3.03 | 2 | 12 | 4 |

TABLE 5-32. RECHARGE STATISTICS FOR THE MIAMI RIVER BASIN

TABLE 5-32 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3262700 GREAT MIAMI RIVER AT TROY, OHIO | | | | | | | | | | | | | | |
| 63 | 170000. | 148000. | 108000. | 50. | 44. | 32. | 3.58 | 3.12 | 2.27 | 7.15 | 3.92 | 2 | 21 | 5 |
| 67 | 277000. | 290000. | 237000. | 44. | 47. | 38. | 5.82 | 6.11 | 4.99 | 13.12 | 3.92 | 2 | 21 | 5 |
| 73 | 603000. | 586000. | 568000. | 52. | 51. | 49. | 12.68 | 12.32 | 11.95 | 24.37 | 3.92 | 2 | 21 | 5 |
| 3263000 GREAT MIAMI RIVER AT TAYLORSVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 144000. | 141000. | 162000. | 38. | 43. | 37. | 3.03 | 3.41 | 3.42 | 7.99 | 4.09 | 2 | 21 | 5 |
| 67 | 248000. | 282000. | 241000. | 40. | 45. | 39. | 5.22 | 5.93 | 5.94 | 13.07 | 4.09 | 2 | 21 | 5 |
| 73 | 583000. | 567000. | 566000. | 52. | 50. | 50. | 12.25 | 11.92 | 12.06 | 23.69 | 4.09 | 2 | 21 | 5 |
| 3264000 GREENVILLE CREEK NEAR BRADFORD, OHIO | | | | | | | | | | | | | | |
| 63 | 222000. | 219000. | 198000. | 55. | 54. | 49. | 4.67 | 4.62 | 4.17 | 8.55 | 2.86 | 2 | 12 | 5 |
| 67 | 389000. | 418000. | 364000. | 52. | 56. | 49. | 8.19 | 8.79 | 7.66 | 15.68 | 2.86 | 2 | 12 | 5 |
| 73 | 558000. | 568000. | 546000. | 57. | 58. | 55. | 11.73 | 11.94 | 11.48 | 20.73 | 2.86 | 2 | 12 | 5 |
| 3265000 STILLWATER RIVER AT PLEASANT HILL, OHIO | | | | | | | | | | | | | | |
| 63 | 174000. | 160000. | 134000. | 45. | 41. | 34. | 3.66 | 3.36 | 2.82 | 8.18 | 3.47 | 2 | 12 | 5 |
| 67 | 255000. | 278000. | 260000. | 37. | 41. | 38. | 5.36 | 5.86 | 5.48 | 14.42 | 3.47 | 2 | 12 | 5 |
| 73 | 421000. | 437000. | 443000. | 42. | 43. | 44. | 8.86 | 9.19 | 9.32 | 21.34 | 3.47 | 2 | 12 | 5 |
| 3266000 STILLWATER RIVER AT ENGLEWOOD, OHIO | | | | | | | | | | | | | | |
| 63 | 186000. | 182000. | 135000. | 47. | 46. | 34. | 3.92 | 3.84 | 2.85 | 8.38 | 3.65 | 2 | 21 | 5 |
| 67 | 279000. | 315000. | 255000. | 37. | 42. | 34. | 5.87 | 6.63 | 5.37 | 15.72 | 3.65 | 2 | 21 | 5 |
| 73 | 452000. | 473000. | 493000. | 46. | 48. | 50. | 9.51 | 9.94 | 10.36 | 20.60 | 3.65 | 2 | 21 | 5 |

TABLE 5-32 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3266500 MAD RIVER AT ZANESFIELD, OHIO | | | | | | | | | | | | | | |
| 63 | 269000. | 322000. | 248000. | 47. | 56. | 43. | 5.67 | 6.78 | 5.23 | 12.15 | 1.49 | 2 | 13 | 4 |
| 67 | 536000. | 534000. | 509000. | 72. | 72. | 68. | 11.26 | 11.22 | 10.70 | 15.67 | 1.49 | 2 | 13 | 4 |
| 73 | 769000. | 791000. | 733000. | 71. | 73. | 68. | 16.15 | 16.64 | 15.41 | 22.81 | 1.49 | 2 | 13 | 4 |
| 3267000 MAD RIVER NEAR URBANA, OHIO | | | | | | | | | | | | | | |
| 63 | 249000. | 246000. | 238000. | 64. | 63. | 61. | 5.24 | 5.18 | 5.00 | 8.17 | 2.77 | 2 | 21 | 4 |
| 67 | 420000. | 420000. | 406000. | 79. | 79. | 76. | 8.83 | 8.84 | 8.54 | 11.25 | 2.77 | 2 | 21 | 4 |
| 73 | 782000. | 774000. | 761000. | 82. | 81. | 80. | 16.43 | 16.27 | 15.99 | 20.07 | 2.77 | 2 | 21 | 4 |
| 3267500 MAD RIVER AT TREMONT CITY, OHIO | | | | | | | | | | | | | | |
| 67 | 423000. | 428000. | 423000. | 76. | 76. | 75. | 8.90 | 8.99 | 8.89 | 11.78 | 3.05 | 2 | 21 | 4 |
| 73 | 725000. | 733000. | 721000. | 76. | 77. | 76. | 15.24 | 15.40 | 15.16 | 20.06 | 3.05 | 2 | 21 | 4 |
| 3267700 MOORE RUN NEAR EAGLE CITY, OHIO | | | | | | | | | | | | | | |
| 67 | 490000. | 490000. | 486000. | 91. | 91. | 90. | 10.31 | 10.31 | 10.22 | 11.38 | 1.79 | 2 | 21 | 4 |
| 3267800 MAD RIVER AT EAGLE CITY, OHIO | | | | | | | | | | | | | | |
| 67 | 392000. | 398000. | 394000. | 71. | 72. | 71. | 8.24 | 8.37 | 8.29 | 11.60 | 3.14 | 2 | 21 | 4 |
| 3267900 MAD RIVER (ST. PARIS PIKE) AT EAGLE CITY, OHIO | | | | | | | | | | | | | | |
| 67 | 392000. | 395000. | 386000. | 72. | 73. | 71. | 8.24 | 8.31 | 8.11 | 11.41 | 3.15 | 2 | 21 | 4 |
| 73 | 693000. | 701000. | 691000. | 68. | 69. | 68. | 14.57 | 14.73 | 14.52 | 21.38 | 3.15 | 2 | 21 | 4 |

TABLE 5-32 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3267950 BUCK CREEK NEAR NEW MOOREFIELD, OHIO | | | | | | | | | | | | | | |
| 67 | 181000. | 182000. | 182000. | 90. | 91. | 91. | 3.82 | 3.83 | 3.83 | 4.22 | 1.98 | 2 | 21 | 4 |
| 73 | 785000. | 792000. | 778000. | 89. | 90. | 88. | 16.50 | 16.64 | 16.36 | 18.56 | 1.98 | 2 | 21 | 4 |
| 3267960 EAST FORK BUCK CREEK NEAR NEW MOOREFIELD, OHIO | | | | | | | | | | | | | | |
| 67 | 0. | 0. | 0. | 0. | 0. | 0. | 0.0 | 0.0 | 0.0 | 6.66 | 1.96 | 2 | 21 | 4 |
| 73 | 906000. | 906000. | 843000. | 75. | 76. | 70. | 19.03 | 19.05 | 17.71 | 25.22 | 1.96 | 2 | 21 | 4 |
| 3268500 BEAVER CREEK NEAR SPRINGFIELD, OHIO | | | | | | | | | | | | | | |
| 73 | 510000. | 511000. | 501000. | 61. | 61. | 60. | 10.72 | 10.74 | 10.53 | 17.64 | 2.08 | 2 | 21 | 4 |
| 3269500 MAD RIVER NEAR SPRINGFIELD, OHIO | | | | | | | | | | | | | | |
| 63 | 313000. | 306000. | 300000. | 61. | 59. | 58. | 6.58 | 6.44 | 6.31 | 10.84 | 3.45 | 2 | 21 | 5 |
| 67 | 410000. | 411000. | 407000. | 71. | 72. | 71. | 8.62 | 8.65 | 8.57 | 12.08 | 3.45 | 2 | 21 | 5 |
| 73 | 758000. | 758000. | 749000. | 73. | 73. | 72. | 15.93 | 15.94 | 15.73 | 21.84 | 3.45 | 2 | 21 | 5 |
| 3270000 MAD RIVER NEAR DAYTON, OHIO | | | | | | | | | | | | | | |
| 63 | 311000. | 301000. | 289000. | 58. | 56. | 54. | 6.54 | 6.33 | 6.08 | 11.26 | 3.64 | 2 | 21 | 5 |
| 67 | 411000. | 412000. | 401000. | 72. | 72. | 71. | 8.63 | 8.66 | 8.44 | 11.94 | 3.64 | 2 | 21 | 5 |
| 73 | 739000. | 732000. | 726000. | 73. | 72. | 72. | 15.54 | 15.38 | 15.25 | 21.33 | 3.64 | 2 | 21 | 5 |
| 3270500 GREAT MIAMI RIVER AT DAYTON, OHIO | | | | | | | | | | | | | | |
| 63 | 177000. | 196000. | 172000. | 43. | 48. | 42. | 3.72 | 4.13 | 4.14 | 8.67 | 4.79 | 2 | 21 | 5 |
| 67 | 277000. | 308000. | 258000. | 45. | 50. | 41. | 5.84 | 6.47 | 6.48 | 13.03 | 4.79 | 2 | 21 | 5 |
| 73 | 601000. | 588000. | 552000. | 56. | 55. | 52. | 12.64 | 12.36 | 12.47 | 22.46 | 4.79 | 2 | 21 | 5 |

TABLE 5-32 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| 3270800 WOLF CREEK AT TROTWOOD, OHIO | | | | | | | | | | | | | | |
| 63 | 148000. | 171000. | 131000. | 37. | 43. | 33. | 3.11 | 3.60 | 2.76 | 8.43 | 1.87 | 2 | 21 | 5 |
| 67 | 408000. | 414000. | 351000. | 52. | 52. | 44. | 8.58 | 8.70 | 7.39 | 16.63 | 1.87 | 2 | 21 | 5 |
| 73 | 502000. | 526000. | 440000. | 51. | 53. | 44. | 10.56 | 11.07 | 9.25 | 20.88 | 1.87 | 2 | 21 | 5 |
| 3271500 GREAT MIAMI RIVER AT MIAMISBURG, OHIO | | | | | | | | | | | | | | |
| 63 | 205000. | 223000. | 203000. | 47. | 51. | 46. | 4.32 | 4.69 | 4.70 | 9.26 | 4.86 | 2 | 21 | 5 |
| 67 | 313000. | 344000. | 307000. | 48. | 53. | 47. | 6.59 | 7.24 | 7.25 | 13.75 | 4.86 | 2 | 21 | 5 |
| 73 | 618000. | 607000. | 576000. | 59. | 58. | 55. | 12.98 | 12.75 | 12.84 | 22.13 | 4.86 | 2 | 21 | 5 |
| 3271800 TWIN CREEK NEAR INGOMAR, OHIO | | | | | | | | | | | | | | |
| 63 | 143000. | 147000. | 136000. | 34. | 35. | 32. | 3.01 | 3.11 | 2.86 | 8.92 | 2.88 | 2 | 12 | 5 |
| 67 | 347000. | 382000. | 387000. | 39. | 43. | 43. | 7.30 | 8.03 | 8.14 | 18.83 | 2.88 | 2 | 12 | 5 |
| 73 | 454000. | 454000. | 435000. | 45. | 46. | 44. | 9.54 | 9.55 | 9.15 | 20.99 | 2.88 | 2 | 12 | 5 |
| 3272000 TWIN CREEK NEAR GERMANTOWN, OHIO | | | | | | | | | | | | | | |
| 63 | 142000. | 129000. | 101000. | 35. | 32. | 25. | 2.99 | 2.72 | 2.13 | 8.52 | 3.08 | 2 | 21 | 5 |
| 67 | 317000. | 323000. | 297000. | 40. | 41. | 38. | 6.67 | 6.80 | 6.24 | 16.59 | 3.08 | 2 | 21 | 5 |
| 73 | 430000. | 441000. | 443000. | 42. | 43. | 43. | 9.05 | 9.27 | 9.32 | 21.71 | 3.08 | 2 | 21 | 5 |
| 3272800 SEVENMILE CREEK AT COLLINSVILLE, OHIO | | | | | | | | | | | | | | |
| 63 | 154000. | 158000. | 137000. | 38. | 38. | 33. | 3.25 | 3.33 | 2.88 | 8.65 | 2.61 | 2 | 21 | 5 |
| 67 | 364000. | 384000. | 317000. | 47. | 49. | 41. | 7.65 | 8.07 | 6.66 | 16.42 | 2.61 | 2 | 21 | 5 |

TABLE 5-32 CONTINUED

| | RECHARGE RATE, GPD/SQ.MI. | | | GW, PERCENT | | | GW, IN INCHES | | | DIS | N | GEOLOGY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YR | FIXED | SLIDING | LOCMIN | FX | SL | LM | FX | SL | LM | IN | DAYS | REL | SUR | BRK |
| **3274000 GREAT MIAMI RIVER AT HAMILTON, OHIO** | | | | | | | | | | | | | | |
| 63 | 222000. | 209000. | 210000. | 52. | 49. | 49. | 4.68 | 4.40 | 4.42 | 9.05 | 5.15 | 2 | 21 | 5 |
| 67 | 328000. | 319000. | 263000. | 50. | 48. | 40. | 6.90 | 6.72 | 6.73 | 13.88 | 5.15 | 2 | 21 | 5 |
| 73 | 556000. | 547000. | 511000. | 54. | 53. | 50. | 11.68 | 11.49 | 11.59 | 21.54 | 5.15 | 2 | 21 | 5 |
| **3276500 WHITEWATER RIVER AT BROOKVILLE, IND.** | | | | | | | | | | | | | | |
| 67 | 350000. | 370000. | 371000. | 46. | 48. | 48. | 7.37 | 7.79 | 7.79 | 16.08 | 4.15 | 2 | 10 | 5 |
| 73 | 567000. | 568000. | 529000. | 54. | 54. | 51. | 11.92 | 11.94 | 11.95 | 21.98 | 4.15 | 2 | 10 | 5 |
| **3322500 WABASH RIVER NEAR NEW CORYDON, IND.** | | | | | | | | | | | | | | |
| 67 | 205000. | 225000. | 209000. | 32. | 36. | 33. | 4.32 | 4.74 | 4.41 | 13.34 | 3.05 | 2 | 10 | 4 |
| 73 | 558000. | 565000. | 586000. | 51. | 51. | 53. | 11.73 | 11.88 | 12.31 | 23.14 | 3.05 | 2 | 10 | 4 |

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3260700 BOKENGEHALAS CREEK NEAR DEGRAFF, OHIO | | | | | | | | | |
| 63 | 2.91730 | 1.63299 | 0.10744 | 0.12948 | 0.16529 | 0.22039 | 0.24931 | 0 | 0 |
| 67 | 3.53553 | 2.04820 | 0.17631 | 0.18733 | 0.28237 | 0.44077 | 0.52342 | 0 | 0 |
| 73 | 2.44949 | 1.64751 | 0.44077 | 0.49587 | 0.77135 | 0.93664 | 1.12948 | 0 | 0 |
| 3260800 STONY CREEK NEAR DEGRAFF, OHIO | | | | | | | | | |
| 63 | 2.75284 | 1.59861 | 0.10152 | 0.10829 | 0.15228 | 0.18613 | 0.23689 | 0 | 0 |
| 67 | 3.24808 | 1.90394 | 0.15059 | 0.16920 | 0.23689 | 0.32149 | 0.40609 | 0 | 0 |
| 73 | 2.29285 | 1.56654 | 0.55838 | 0.59222 | 0.78257 | 0.98139 | 1.11675 | 0 | 0 |
| 3261500 GREAT MIAMI RIVER AT SIDNEY, OHIO | | | | | | | | | |
| 63 | 4.36592 | 2.20721 | 0.03882 | 0.04529 | 0.07209 | 0.10166 | 0.14787 | 0 | 0 |
| 67 | 5.86786 | 2.97699 | 0.07209 | 0.08133 | 0.12431 | 0.22181 | 0.29852 | 0 | 0 |
| 73 | 3.56328 | 2.22008 | 0.22921 | 0.30499 | 0.48660 | 0.89649 | 1.21996 | 0 | 0 |
| 3261950 LORAMIE CREEK NEAR NEWPORT, OHIO | | | | | | | | | |
| 67 | 23.77557 | 8.90693 | 0.00322 | 0.00474 | 0.00987 | 0.03553 | 0.11184 | 0 | 0 |
| 73 | 11.94170 | 3.33167 | 0.01645 | 0.03158 | 0.16447 | 0.38158 | 0.72039 | 0 | 0 |
| 3262000 LORAMIE CREEK AT LOCKINGTON, OHIO | | | | | | | | | |
| 63 | 6.41582 | 2.43864 | 0.01128 | 0.01673 | 0.02568 | 0.03268 | 0.03852 | 0 | 0 |
| 67 | 11.70826 | 4.76628 | 0.01751 | 0.01868 | 0.03580 | 0.07782 | 0.15175 | 0 | 0 |
| 73 | 5.98609 | 2.95512 | 0.08949 | 0.11673 | 0.22568 | 0.41245 | 0.77043 | 0 | 0 |

TABLE 5-33. FLOW-RATIO STATISTICS FOR THE MIAMI RIVER BASIN

TABLE 5-33 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3262700 GREAT MIAMI RIVER AT TROY, OHIO | | | | | | | | | |
| 63 | 4.18671 | 2.15991 | 0.02700 | 0.03780 | 0.06210 | 0.08639 | 0.12473 | 0 | 0 |
| 67 | 6.51920 | 2.98989 | 0.05940 | 0.06479 | 0.11150 | 0.21058 | 0.28078 | 0 | 0 |
| 73 | 3.81498 | 2.26738 | 0.22354 | 0.28456 | 0.45950 | 0.85529 | 1.15551 | 0 | 0 |
| 3263000 GREAT MIAMI RIVER AT TAYLORSVILLE, OHIO | | | | | | | | | |
| 63 | 4.14997 | 1.96304 | 0.04178 | 0.05483 | 0.08616 | 0.12185 | 0.15579 | 0 | 0 |
| 67 | 6.08183 | 2.91843 | 0.07050 | 0.07659 | 0.12620 | 0.25239 | 0.33377 | 0 | 0 |
| 73 | 3.32059 | 1.98592 | 0.26458 | 0.33072 | 0.55831 | 0.93995 | 1.19669 | 0 | 0 |
| 3264000 GREENVILLE CREEK NEAR BRADFORD, OHIO | | | | | | | | | |
| 63 | 3.77077 | 1.68766 | 0.05699 | 0.08290 | 0.14508 | 0.18135 | 0.19689 | 0 | 0 |
| 67 | 5.00908 | 2.59666 | 0.09326 | 0.11399 | 0.17617 | 0.37824 | 0.52850 | 0 | 0 |
| 73 | 3.69732 | 1.96531 | 0.21762 | 0.24352 | 0.48964 | 0.72539 | 0.90674 | 0 | 0 |
| 3265000 STILLWATER RIVER AT PLEASANT HILL, OHIO | | | | | | | | | |
| 63 | 4.15211 | 1.80739 | 0.03579 | 0.04970 | 0.08946 | 0.11730 | 0.12922 | 0 | 0 |
| 67 | 6.23222 | 2.92047 | 0.05765 | 0.06859 | 0.11928 | 0.24851 | 0.34592 | 0 | 0 |
| 73 | 3.98292 | 2.11308 | 0.14911 | 0.21869 | 0.42744 | 0.56461 | 0.74553 | 0 | 0 |
| 3266000 STILLWATER RIVER AT ENGLEWOOD, OHIO | | | | | | | | | |
| 63 | 4.56590 | 1.93309 | 0.03077 | 0.04538 | 0.08769 | 0.11385 | 0.12615 | 0 | 0 |
| 67 | 6.68386 | 2.83202 | 0.05692 | 0.07077 | 0.13231 | 0.28154 | 0.37231 | 0 | 0 |
| 73 | 3.99106 | 2.00717 | 0.16769 | 0.21538 | 0.45538 | 0.61385 | 0.84154 | 0 | 0 |

TABLE 5-33 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3266500 MAD RIVER AT ZANESFIELD, OHIO | | | | | | | | | |
| 63 | 2.77980 | 1.54919 | 0.10959 | 0.15068 | 0.20548 | 0.24658 | 0.26027 | 0 | 0 |
| 67 | 3.36650 | 2.23607 | 0.16438 | 0.20548 | 0.27397 | 0.50685 | 0.65753 | 0 | 0 |
| 73 | 3.13050 | 1.84999 | 0.30137 | 0.34247 | 0.64041 | 0.90411 | 1.09589 | 0 | 0 |
| 3267000 MAD RIVER NEAR URBANA, OHIO | | | | | | | | | |
| 63 | 1.91485 | 1.33012 | 0.19136 | 0.20370 | 0.24074 | 0.27160 | 0.29630 | 0 | 0 |
| 67 | 2.30714 | 1.48940 | 0.26543 | 0.29630 | 0.43827 | 0.50000 | 0.55556 | 0 | 0 |
| 73 | 1.69615 | 1.33622 | 0.59877 | 0.80247 | 0.97839 | 1.16049 | 1.26543 | 0 | 0 |
| 3267500 MAD RIVER AT TREMONT CITY, OHIO | | | | | | | | | |
| 67 | 2.12891 | 1.47867 | 0.32576 | 0.35227 | 0.46212 | 0.54167 | 0.59470 | 0 | 0 |
| 73 | 1.77904 | 1.36862 | 0.62121 | 0.75758 | 0.94034 | 1.11742 | 1.24242 | 0 | 0 |
| 3267700 MOORE RUN NEAR EAGLE CITY, OHIO | | | | | | | | | |
| 67 | 1.34840 | 1.19024 | 0.53846 | 0.60440 | 0.65934 | 0.71429 | 0.76923 | 0 | 0 |
| 3267800 MAD RIVER AT EAGLE CITY, OHIO | | | | | | | | | |
| 67 | 2.26017 | 1.56898 | 0.30945 | 0.33062 | 0.40391 | 0.46580 | 0.52117 | 0 | 0 |
| 3267900 MAD RIVER (ST. PARIS PIKE) AT EAGLE CITY, OHIO | | | | | | | | | |
| 67 | 2.19089 | 1.57017 | 0.32258 | 0.33871 | 0.39677 | 0.46452 | 0.53226 | 0 | 0 |
| 73 | 1.85917 | 1.37822 | 0.67742 | 0.74194 | 0.93065 | 1.05161 | 1.19839 | 0 | 0 |

TABLE 5-33 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3267950 BUCK CREEK NEAR NEW MOOREFIELD, OHIO | | | | | | | | | |
| 67 | 2.66659 | 1.78088 | 0.32787 | 0.36066 | 0.55738 | 0.78689 | 2.51803 | 182 | 0 |
| 73 | 1.38962 | 1.18065 | 0.68852 | 0.95082 | 1.08197 | 1.21311 | 1.27869 | 0 | 0 |
| 3267960 EAST FORK BUCK CREEK NEAR NEW MOOREFIELD, OHIO | | | | | | | | | |
| 67 | 1.94009 | 1.47114 | 0.41812 | 0.48780 | 0.69686 | 1.18467 | 5.86582 | 182 | 0 |
| 73 | 2.19659 | 1.37957 | 0.62718 | 0.69686 | 1.08014 | 1.32404 | 1.44599 | 0 | 0 |
| 3268500 BEAVER CREEK NEAR SPRINGFIELD, OHIO | | | | | | | | | |
| 73 | 2.42033 | 2.10555 | 0.43367 | 0.57398 | 0.76531 | 1.02041 | 1.27551 | 61 | 0 |
| 3269500 MAD RIVER NEAR SPRINGFIELD, OHIO | | | | | | | | | |
| 63 | 1.93384 | 1.31306 | 0.26327 | 0.29796 | 0.35510 | 0.38776 | 0.40408 | 0 | 0 |
| 67 | 2.23865 | 1.53124 | 0.33878 | 0.35306 | 0.43367 | 0.51429 | 0.57143 | 0 | 0 |
| 73 | 1.88208 | 1.36544 | 0.67551 | 0.74898 | 1.03878 | 1.21224 | 1.37551 | 0 | 0 |
| 3270000 MAD RIVER NEAR DAYTON, OHIO | | | | | | | | | |
| 63 | 2.24172 | 1.40894 | 0.23622 | 0.24882 | 0.31732 | 0.36063 | 0.39685 | 0 | 0 |
| 67 | 2.38966 | 1.63239 | 0.28346 | 0.29370 | 0.39685 | 0.51181 | 0.58110 | 0 | 0 |
| 73 | 1.88481 | 1.39781 | 0.63307 | 0.74252 | 0.97323 | 1.17795 | 1.32756 | 0 | 0 |
| 3270500 GREAT MIAMI RIVER AT DAYTON, OHIO | | | | | | | | | |
| 63 | 3.52178 | 1.79520 | 0.06850 | 0.08204 | 0.12605 | 0.17603 | 0.20789 | 0 | 0 |
| 67 | 4.83710 | 2.46190 | 0.09956 | 0.11370 | 0.17971 | 0.30705 | 0.41219 | 0 | 0 |
| 73 | 2.98034 | 1.79675 | 0.32616 | 0.37595 | 0.65412 | 0.97172 | 1.21266 | 0 | 0 |

TABLE 5-33 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3270800 WOLF CREEK AT TROTWOOD, OHIO | | | | | | | | | |
| 63 | 7.74597 | 2.58199 | 0.01762 | 0.01762 | 0.03965 | 0.06167 | 0.08370 | 0 | 0 |
| 67 | 10.08032 | 2.56850 | 0.00881 | 0.02731 | 0.15859 | 0.29515 | 0.40088 | 0 | 4 |
| 73 | 5.00000 | 2.40966 | 0.09692 | 0.12775 | 0.27313 | 0.52863 | 0.74890 | 0 | 0 |
| 3271500 GREAT MIAMI RIVER AT MIAMISBURG, OHIO | | | | | | | | | |
| 63 | 2.91250 | 1.59600 | 0.10992 | 0.12763 | 0.17088 | 0.20583 | 0.23737 | 0 | 0 |
| 67 | 4.19277 | 2.23341 | 0.14533 | 0.15695 | 0.23331 | 0.37256 | 0.47215 | 0 | 0 |
| 73 | 2.72966 | 1.70018 | 0.37256 | 0.43342 | 0.71653 | 1.00332 | 1.21357 | 0 | 0 |
| 3271800 TWIN CREEK NEAR INGOMAR, OHIO | | | | | | | | | |
| 63 | 4.86504 | 1.86190 | 0.02944 | 0.04289 | 0.07614 | 0.08629 | 0.10152 | 0 | 0 |
| 67 | 6.82500 | 2.41091 | 0.05584 | 0.07868 | 0.20305 | 0.36548 | 0.47208 | 0 | 0 |
| 73 | 6.69064 | 2.65957 | 0.07614 | 0.08629 | 0.24239 | 0.50254 | 0.71066 | 0 | 0 |
| 3272000 TWIN CREEK NEAR GERMANTOWN, OHIO | | | | | | | | | |
| 63 | 5.46761 | 2.10159 | 0.01927 | 0.03455 | 0.06545 | 0.08727 | 0.09455 | 0 | 0 |
| 67 | 6.39078 | 2.42530 | 0.04727 | 0.06909 | 0.19273 | 0.34545 | 0.46000 | 0 | 0 |
| 73 | 6.13829 | 2.41164 | 0.08000 | 0.10182 | 0.30636 | 0.58182 | 0.84000 | 0 | 0 |
| 3272800 SEVENMILE CREEK AT COLLINSVILLE, OHIO | | | | | | | | | |
| 63 | 6.18016 | 2.48633 | 0.01667 | 0.03000 | 0.04583 | 0.06500 | 0.08333 | 0 | 0 |
| 67 | 5.42720 | 2.55333 | 0.06167 | 0.09167 | 0.16042 | 0.34167 | 0.47500 | 0 | 0 |

TABLE 5-33 CONTINUED

| YR | RT10/90 | RT25/75 | Q95 | Q90 | Q75 | Q60 | Q50 | # MISSING | NO FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 3274000 GREAT MIAMI RIVER AT HAMILTON, OHIO | | | | | | | | | |
| 63 | 3.39627 | 1.74904 | 0.09036 | 0.11129 | 0.14904 | 0.18623 | 0.22755 | 0 | 0 |
| 67 | 4.59870 | 2.32921 | 0.12094 | 0.13678 | 0.22190 | 0.38292 | 0.47521 | 0 | 0 |
| 73 | 2.90984 | 1.71379 | 0.30579 | 0.37741 | 0.68939 | 0.97245 | 1.18870 | 0 | 0 |
| 3276500 WHITEWATER RIVER AT BROOKVILLE, IND. | | | | | | | | | |
| 67 | 4.55154 | 2.39100 | 0.12173 | 0.13113 | 0.22651 | 0.45670 | 0.60703 | 0 | 0 |
| 73 | 3.75122 | 1.88344 | 0.22141 | 0.25082 | 0.56944 | 0.83333 | 1.07843 | 0 | 0 |
| 3322500 WABASH RIVER NEAR NEW CORYDON, IND. | | | | | | | | | |
| 67 | 9.10465 | 4.33235 | 0.02290 | 0.02901 | 0.04962 | 0.09160 | 0.14695 | 0 | 0 |
| 73 | 4.24830 | 2.33768 | 0.13359 | 0.19847 | 0.36546 | 0.77481 | 1.14504 | 0 | 0 |

MIAMI BASIN

| | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 3260700 BOKENGEHALAS CREEK NEAR DEGRAFF, OHIO | | | | | | | | | | | | |
| FX | 78000. | 161000. | 151000. | 146000. | 203000. | 1132000. | 449000. | 230000. | 146000. | 100000. | 102000. | 55000. |
| SL | 79000. | 156000. | 148000. | 152000. | 213000. | 1036000. | 452000. | 229000. | 146000. | 101000. | 101000. | 57000. |
| LM | 80000. | 145000. | 150000. | 141000. | 158000. | 941000. | 469000. | 224000. | 150000. | 102000. | 102000. | 76000. |
| 67 | | | | | | | | | | | | |
| FX | 97000. | 244000. | 531000. | 249000. | 354000. | 1100000. | 703000. | 901000. | 338000. | 206000. | 178000. | 119000. |
| SL | 95000. | 276000. | 591000. | 252000. | 366000. | 1060000. | 709000. | 924000. | 340000. | 202000. | 186000. | 120000. |
| LM | 93000. | 193000. | 332000. | 261000. | 321000. | 1031000. | 681000. | 929000. | 350000. | 206000. | 178000. | 118000. |
| 73 | | | | | | | | | | | | |
| FX | 420000. | 986000. | 968000. | 627000. | 559000. | 1212000. | 1307000. | 752000. | 478000. | 488000. | 655000. | 255000. |
| SL | 423000. | 1064000. | 956000. | 628000. | 560000. | 1171000. | 1297000. | 749000. | 491000. | 454000. | 523000. | 252000. |
| LM | 401000. | 1030000. | 964000. | 661000. | 522000. | 1184000. | 1263000. | 700000. | 478000. | 406000. | 302000. | 255000. |
| 67 3261950 LORAMIE CREEK NEAR NEWPORT, OHIO | | | | | | | | | | | | |
| FX | 2775. | 53000. | 474000. | 82000. | 180000. | 1192000. | 254000. | 809000. | 48000. | 16000. | 3429. | 2395. |
| SL | 2580. | 78000. | 698000. | 79000. | 217000. | 1137000. | 295000. | 727000. | 49000. | 14000. | 3160. | 2382. |
| LM | 1846. | 11000. | 106000. | 78000. | 113000. | 1048000. | 254000. | 808000. | 46000. | 11000. | 3311. | 2160. |
| 73 | | | | | | | | | | | | |
| FX | 280000. | 736000. | 584000. | 254000. | 236000. | 1430000. | 657000. | 172000. | 123000. | 181000. | 536000. | 8397. |
| SL | 302000. | 835000. | 607000. | 276000. | 232000. | 1250000. | 686000. | 158000. | 152000. | 134000. | 305000. | 8399. |
| LM | 252000. | 798000. | 515000. | 273000. | 220000. | 1137000. | 596000. | 132000. | 81000. | 85000. | 104000. | 11000. |
| 63 3267000 MAD RIVER NEAR URBANA, OHIO | | | | | | | | | | | | |
| FX | 153000. | 180000. | 166000. | 159000. | 186000. | 787000. | 387000. | 282000. | 244000. | 176000. | 138000. | 119000. |
| SL | 154000. | 176000. | 166000. | 159000. | 184000. | 762000. | 388000. | 278000. | 241000. | 176000. | 139000. | 119000. |
| LM | 155000. | 173000. | 167000. | 157000. | 184000. | 646000. | 411000. | 276000. | 241000. | 177000. | 140000. | 119000. |
| 67 | | | | | | | | | | | | |
| FX | 165000. | 262000. | 433000. | 292000. | 318000. | 862000. | 613000. | 776000. | 436000. | 344000. | 296000. | 228000. |
| SL | 164000. | 265000. | 455000. | 291000. | 319000. | 839000. | 617000. | 773000. | 434000. | 342000. | 299000. | 230000. |
| LM | 163000. | 215000. | 309000. | 293000. | 305000. | 826000. | 608000. | 823000. | 444000. | 344000. | 298000. | 230000. |
| 73 | | | | | | | | | | | | |
| FX | 374000. | 807000. | 820000. | 654000. | 614000. | 1083000. | 1259000. | 839000. | 708000. | 863000. | 793000. | 555000. |
| SL | 377000. | 841000. | 814000. | 662000. | 612000. | 1047000. | 1259000. | 836000. | 717000. | 826000. | 736000. | 555000. |
| LM | 361000. | 842000. | 808000. | 674000. | 591000. | 984000. | 1253000. | 830000. | 707000. | 802000. | 717000. | 552000. |

TABLE 5-34. MONTHLY RECHARGE RATES IN THE MIAMI RIVER BASIN

the northwest. Small portions of some of the more southwesterly basins lie in Indiana. Most of the Indiana drainage (1340 sq. mi.) is in the Whitewater River basin.

The average gradient of the Miami River is 3.9 feet per mile. Gradients for the major tributaries range from 1.9 for Whitewater River to 16.6 for Talawanda Creek. Most gradients are moderate, except for Talawanda (Fourmile) and Sevenmile Creek, which originate at a high elevation.

Bedrock in the basin ranges in age from Ordovician to Silurian and consists of limestone, dolomite and shale. Most of these formations are quite dense and do not yield appreciable amounts of water, except possibly in the north where porous dolomites may contribute minor amounts to base flow. The primary reason for high base flow in this basin is the presence of extensive deposits of sand and gravel along many of the water courses. Thickness exceed 300 feet in the north, although they thin southward. Thick till plains areas provide only a moderate contribution to streamflow.

Well yields in the basin range from less than 5 gpm in thick till overlying shale to more than 1000 gpm in permeable sand and gravel adjacent to the Miami and Mad Rivers. Areas that yield more than 100 gpm from permeable sand and gravel deposits are numerous. Limestone aquifers in the northern section of the basin also yield large amounts of water, but high concentrations of hydrogen sulfide commonly make the water objectionable.

Annual precipitation in the basin during the water years 1963, 1967, and 1973 ranged from 25 to 35, 30 to 40, and 40 to 50 inches, respectively. The annual precipitation patterns were similar during all three years, with precipitation increasing southward.

Streamflow is usually highest in the spring with lowest flows during late summer. November 1972 was anomalous because of the very high streamflow throughout most of the basin. The range of effective recharge rates and flow indices for the basin is very wide between dry and wet years (Tables 5-32 and 5-33). This leads to the hypothesis that the deposits that exert the strongest control on baseflow can store large quantities of water, but also release it quickly. In a dry year, the water previously stored is slowly released, but the rate declines with the lack of recharge. In wet years, water infiltrates quickly, and ground-water runoff increases as long as precipitation continues to supply an excess volume of water.

The amount of ground water in storage is greatest in the northeast section of the basin and diminishes to the south. Effective recharge rates in the Mad River basin range from 400,000 to 500,000 gpd/sq. mi. during a normal year. The Mad River occupies a broad outwash-filled valley that lies between morainal ridges. The flow indices and recharge rates are the highest in the State due to the extensive deposits of very permeable sand and gravel.

Loramie Creek, to the northwest, drains till plains and has low flow indices. Stillwater River, which flows through a preglacial valley containing moderately permeable outwash deposits, maintains a reasonably high sustained flow. The high effective recharge rate, ranging between 300,000 and 400,000 gpd/sq. mi., is largely due to ground-water runoff from these deposits.

Effective recharge rates below Dayton are anomalously high when compared with low-flow indices. It is probably due to the amount of control on baseflow immediately after storms, which does not affect the low-flow measurements, but does give erroneous results on the ground-water seperation techniques, especially if storms pass through the area more or less regularly at an interval larger than the recession interval of the stream. This is common in this area and the effect is compounded by reservoirs that act to temporarily store water only after large storms and then slowly release it.

Chemical quality of ground-water in the basin is uniformly hard. Hardness ranges from 275 to 600 mg/l in sand and gravel aquifers and dissolved solids from 350 to 700 mg/l, with most analyses falling between 350 to 500. Iron is a serious problem in many areas. It is almost always present in small amounts, but in this basin, many wells have excessive iron that requires removal prior to use. Water from limestone and shale sources is also hard and may also have enough hydrogen sulfide to make the water objectionable. Chloride does not seem to be a problem, probably because of the large amount of water available to dilute the chloride discharged from municipal sewage plants, as well as the high sustained low flow. Except for a few localized areas where cities or industries induce infiltration, the Miami River and Mad River are discharge regions for most of their length.

# Chapter 6

# SUMMARY AND CONCLUSIONS

## Introduction

During the course of this investigation preliminary effective ground-water recharge rates for the entire State of Ohio were determined. The rates were based largely on the separation of stream hydrographs representing years of normal, low, and high precipitation. In some instances the data were believed unreliable because of the influence on streamflow by control structures or mining. In cases such as these, rates were estimated by means of flow-duration curves.

It must be pointed out that the rates described herein are preliminary. Furthermore, the definition of the term "effective ground-water recharge rate" equates it with ground-water runoff - that volume of precipitation that infiltrates and eventually reaches a stream. These rates do not include ground water removed by evapotranspiration, by pumping, or by percolation to deeper aquifers. Nonetheless, the rates are of practical value because they indicate the volume of water available on a regional scale that can be captured for use on a sustained basis. Since the study was regional in nature, the rates can only serve as general guidelines for hydrologists and planners dealing with specific sites. The data clearly show that the rates vary widely from one place to another and from one year to the next. Rocks that exert the strongest influence on ground-water runoff are deposits of sand and gravel and spoil banks in the vicinity of coal mines.

Effective recharge rates determined by the computerized methods described in this report are internally consistent, that is, the exact same rate is calculated for the same set of data each time the program is run. This contrasts significantly with geometrically similar manual techniques. This does not mean they are any more correct than any other method and, in fact, automatic data processing does not permit judgment determinations available to the experienced hydrologist.

On the other hand, computer methods are very rapid and, therefore, inexpensive. Furthermore, the rates are in close agreement with those determined by other investigators in different parts of the country where precipitation exceeds 25 inches per year. Our techniques were applied to the same streamflow data used by other investigators who used other methods in basins in Delaware, Illinois, Minnesota and Pennsylvania. All the results were in close agreement.

Figure 6-1 shows the relation between calculated monthly recharge rates and a ground-water hydrograph. The hydrograph represents a State of Ohio observation well, Ro-6, that is a 6-inch diameter drilled test well, 78 feet deep, that taps a gravel aquifer adjacent to Paint Creek near Bourneville. A U.S. Geological Survey stream gaging station is nearby.

## Average Rates

Recharge rates for predominantly till covered areas are listed in Table 6-1. The differences between a dry year and a normal year and between normal and wet years are about a factor of two. During the dryest periods when evapotranspiration is greatest, monthly recharge rates are usually less than 50,000 gpd/sq. mi. The rates consistently exceed 1,000,000 gpd/sq. mi, in March or April.

Several areas throughout the State are characterized by a preponderance of glacial till and relatively thin ribbons of outwash along some of the stream channels. In cases such as these, the outwash exerts a significant

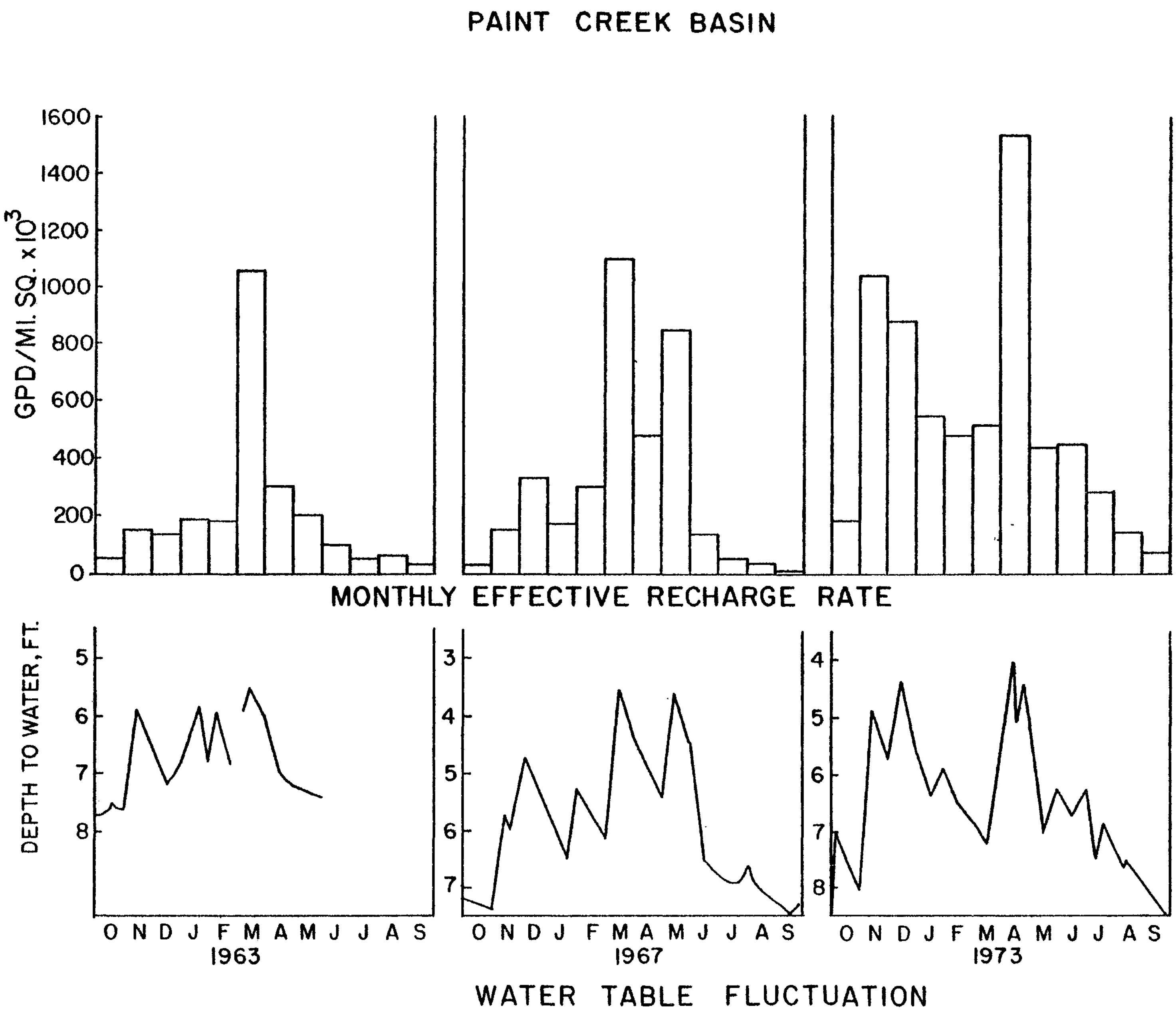



FIGURE 6-1. RELATION BETWEEN CALCULATED EFFECTIVE RECHARGE RATE AND WATER TABLE FLUCTUATION IN PAINT CREEK BASIN

TABLE 6-1 RECHARGE RATES IN TILL COVERED REGIONS

| Precipitation | Effective Recharge Rates, gpd/mi$^2$ | | % of Runoff | | Monthly rates, gpd/mi$^2$ | |
|---|---|---|---|---|---|---|
| | Average | Range | Average | Range | | |
| Dry Year | 106,000 | 62,000-154,000 | 35 | 20-54 | June-Oct | less than 50,000 |
| | | | | | Nov.-Feb. | 100,000- 200,000 |
| | | | | | March | 600,000-1,000,000 |
| | | | | | April | 200,000- 300,000 |
| Normal Year | 219,000 | 123,000-291,000 | 36 | 27-52 | July-Oct. | less than 50,000 |
| | | | | | Nov.-Feb. | 175,000- 300,000 |
| | | | | | March | 875,000-1,100,000 |
| | | | | | April | 325,000- 475,000 |
| Wet Year | 408,000 | 315,000-583,000 | 43 | 35-66 | July-Oct. | 35,000- 300,000 |
| | | | | | Nov. | 950,000-1,050,000 |
| | | | | | Feb. | 350,000- 475,000 |
| | | | | | April | 900,000-1,500,000 |

TABLE 6-2 RECHARGE RATES IN TILL AND STREAM-SIDE OUTWASH REGIONS

| Precipitation | Effective Recharge Rates, gpd/mi$^2$ | | % of Runoff | | Monthly rates, gpd/mi$^2$ | |
|---|---|---|---|---|---|---|
| | Average | Range | Average | Range | | |
| Low Year | 221,000 | 101,000-328,000 | 45 | 32-70 | June-Oct. | 100,000 |
| | | | | | March | 1,050,000 |
| | | | | | April | 300,000 |
| Normal Year | 312,000 | 209,000-386,000 | 51 | 39-63 | July-Oct. | 50,000 |
| | | | | | March | 1,100,000 |
| | | | | | April | 475,000 |
| Wet Year | 533,000 | 422,000-671,000 | 56 | 43-67 | Aug-Oct | 200,000 |
| | | | | | Jan.-March | 475,000 |
| | | | | | April | 1,500,000 |

TABLE 6-3 RECHARGE RATES IN OUTWASH COVERED REGIONS

| Precipitation | Effective Recharge Rates, $mgd/mi^2$ | | % of Runoff | | Monthly Rates, $mgd/mi^2$ | |
|---|---|---|---|---|---|---|
| | Average | Range | Average | Range | | |
| Low Year | 195,000 | 116,000-245,000 | 49 | 36-65 | July-Jan | 200,000 |
| | | | | | March | 650,000 |
| | | | | | April | 400,000 |
| Normal Year | 352,000 | 310,000-406,000 | 57 | 53-61 | Oct.-Nov | 200,000 |
| | | | | | Dec.-Feb, Aug- | 300,000 |
| | | | | | March, May | 825,000 |
| Wet Year | 644,000 | 503,000-692,000 | 64 | 57-70 | Oct | 400,000 |
| | | | | | Dec, Jan, May | 800,000 |
| | | | | | April | 1,200,000 |
| | | MAD RIVER VALLEY | | | | |
| Dry | 269,000 | 238,000-300,000 | 54 | 43-61 | | |
| Normal | 426,000 | 386,000-509,000 | 74 | 68-91 | | |
| Wet | 746,000 | 691,000-843,000 | 73 | 68-88 | | |

TABLE 6-4 RECHARGE RATES IN BEDROCK AND COAL MINING REGIONS (Thin sandstone, shale & limestone)

| Precipitation | Effective Recharge Rate, gpd/mi$^2$ | | % of Runoff | |
|---|---|---|---|---|
| | Average | Range | Average | Range |
| Low | 120,000 | 100,000-132,000 | 28 | 21-42 |
| Normal | 179,000 | 160,000-198,000 | 35 | 30-46 |
| High | 320,000 | 297,000-339,000 | 36 | 22-54 |
| | | COAL MINING REGIONS | | |
| Low | 282,000 | 264,000-300,000 | 41 | 33-58 |
| Normal | 312,000 | 258,000-367,000 | 51 | 43-60 |
| High | 478,000 | 462,000-520,000 | 57 | 47-70 |

influence on baseflow as shown in Table 6-2. The increase in effective recharge rates is solely due to the permeable nature of the outwash.

Table 6-3 clearly indicates that average effective recharge rates in those areas that contain extensive quantities of outwash are unusually high. This is particularly true in the upper reaches of the Mad River valley, which is covered by highly permeable sand and gravel.

Despite the rugged topography in much of the unglaciated parts of Ohio, effective recharge rates in bedrock areas are perhaps higher than one would first expect (Table 6-4). This is probably due to the fractured nature of much of the surficial bedrock in the State. The tremendous storage capacity of spoil material from coal mining operations and its influence on baseflow is also clearly evident in Table 6-4.

Average recharge rates for the entire State of Ohio are listed in Table 6-5.

## Chemical Quality

One of the purposes of this investigation was to examine the relationship between the quality of shallow ground water and baseflow. It is assumed that most of the water in a stream during low flow originates in the zone of intensive ground-water circulation, which is assumed to be less than a few score feet in thickness.

Since at baseflow, all the water in the stream consists of ground-water runoff, the quality of baseflow should closely approximate ground-water quality. There are, however, situations where this concept is not valid, and these occur when either the shallow ground water or surface flow is contaminated. In Ohio, major sources of contamination include municipal sewage, oil-field brine, acid-mine drainage, and locally, industrial wastes. For those reasons, it is not possible to estimate shallow ground-water quality from baseflow data, particularly with respect to chloride and sulfate concentrations and, in some instances, hardness and dissolved solids.

The dissolved solids concentration in ground water throughout Ohio is shown in Figure 6-2. This map is based on well data in which most of the wells are less than 200 feet deep. Figure 6-2 shows that the most mineralized ground water lies in a broad northeast-southwest trending belt that includes much of the Maumee basin. Throughout this region, dissolved solids generally exceed 500 mg/l. Elsewhere, concentrations are less than 500 mg/l. Figure 6-3 is based entirely on low-flow stream data. The pattern is similar to that shown in Figure 6-2, with two exceptions. In the first case, baseflow in the Maumee basin is somewhat less mineralized than ground water. This difference probably reflects the higher mineral content in the underlying limestone. The second case includes the northeast corner of the State where dissolved solids are less than 250 mg/l.

The concentration of hardness in ground water and baseflow are shown on Figures 6-4 and 6-5, respectively. The hardness of ground water ranges within wide limits, but nonetheless it corresponds closely, as one might expect, with the distribution of dissolved solids.

There appears to be less variation in the hardness of ground-water runoff and the concentrations are slightly less than those contained in shallow aquifers. This may be due in part to chemical reactions that occur as ground water seeps into the stream, when there is a change in chemical equilibrium.

The distribution of chloride and sulfate in shallow ground water is shown in Figures 6-6 and 6-7, respectively. As is evident from the maps, chloride concentration in ground water is generally less than 50 mg/l. On the other hand, sulfate ranges within wide extremes and commonly exceeds 500 mg/l in the Maumee basin.

DISSOLVED SOLIDS

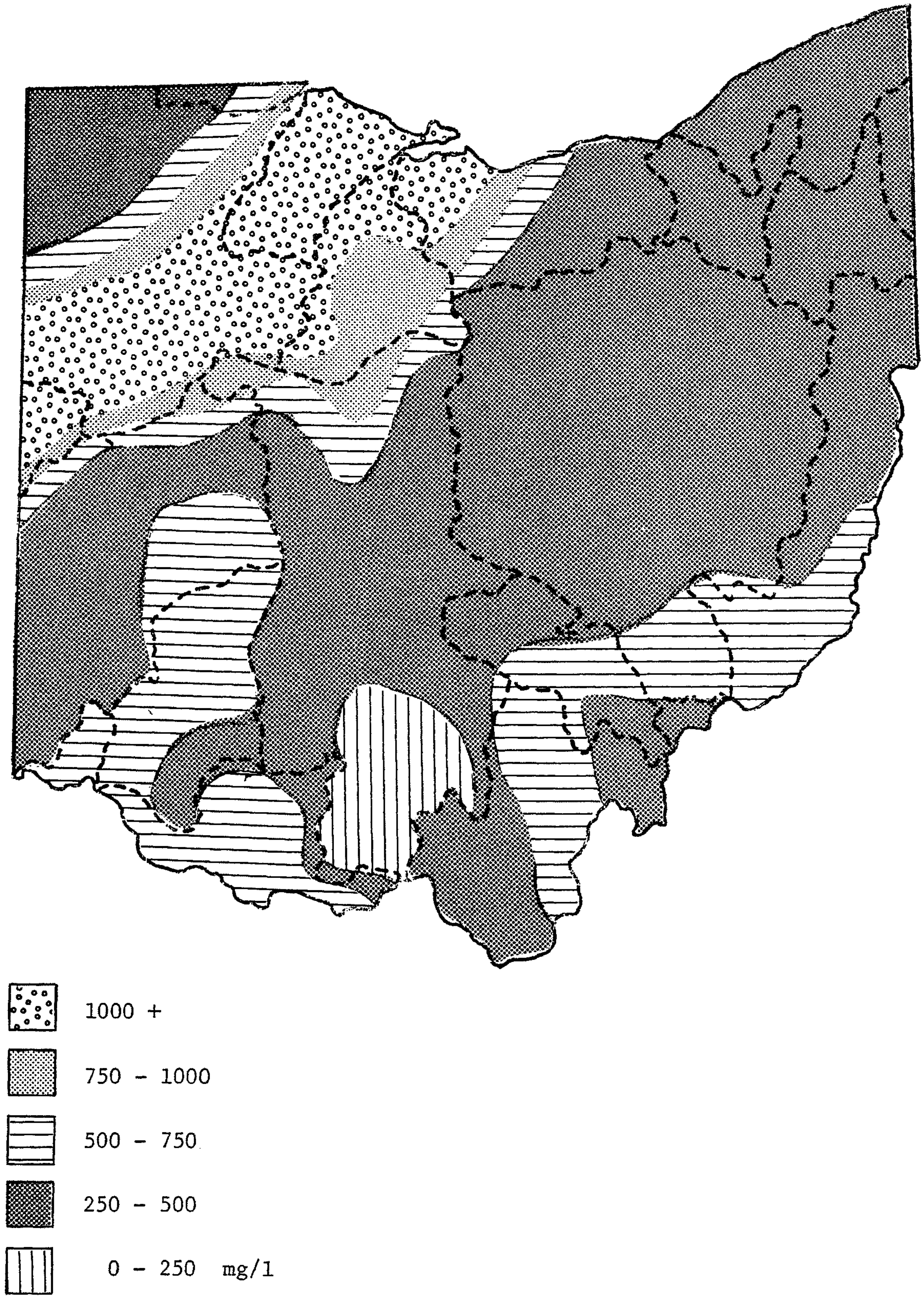



FIGURE 6-2. DISSOLVED SOLIDS CONCENTRATIONS IN GROUND WATER IN OHIO

DISSOLVED SOLIDS
(from low flow)

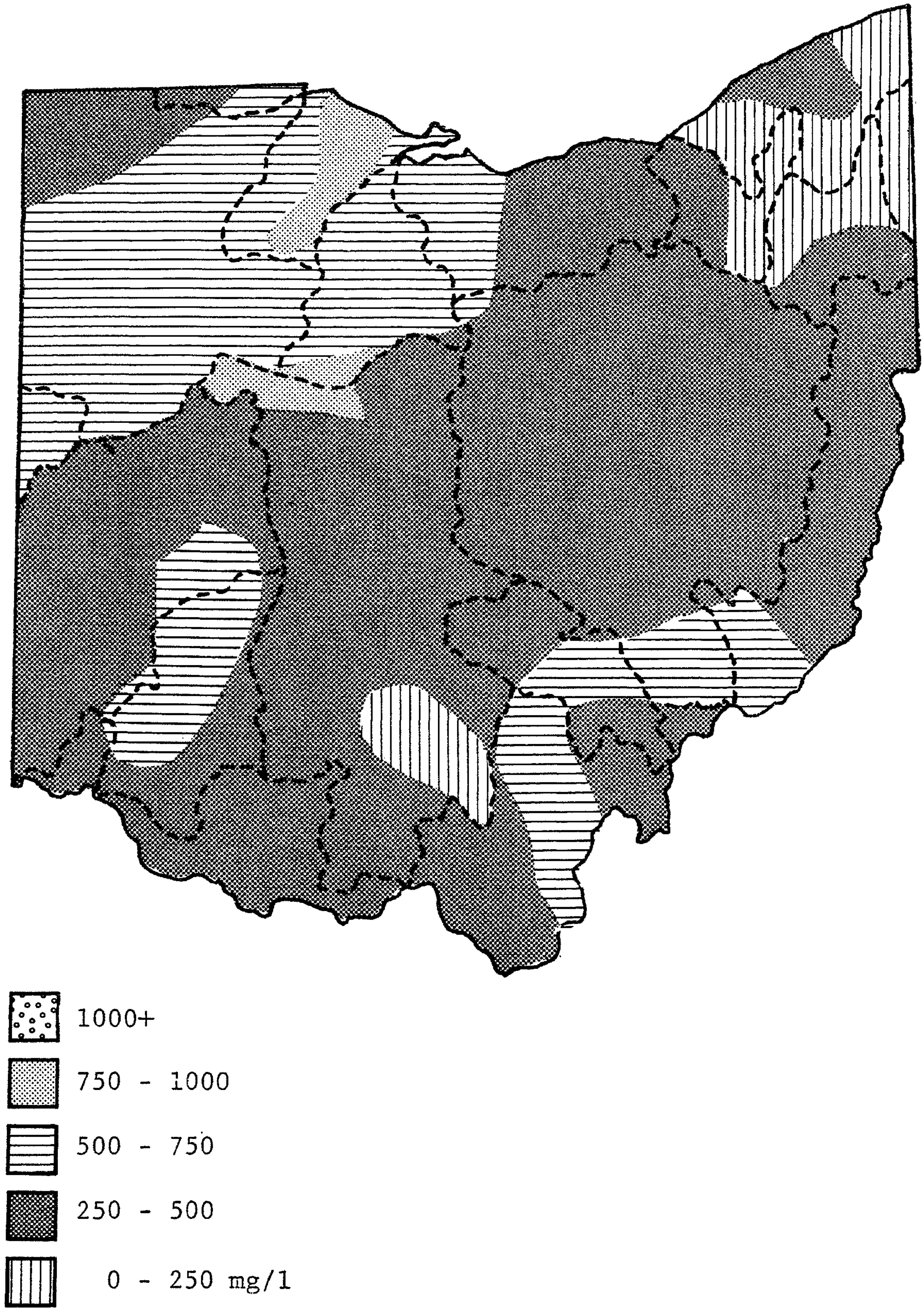



FIGURE 6-3. DISSOLVED SOLIDS CONCENTRATIONS IN OHIO STREAMS DURING LOW FLOW

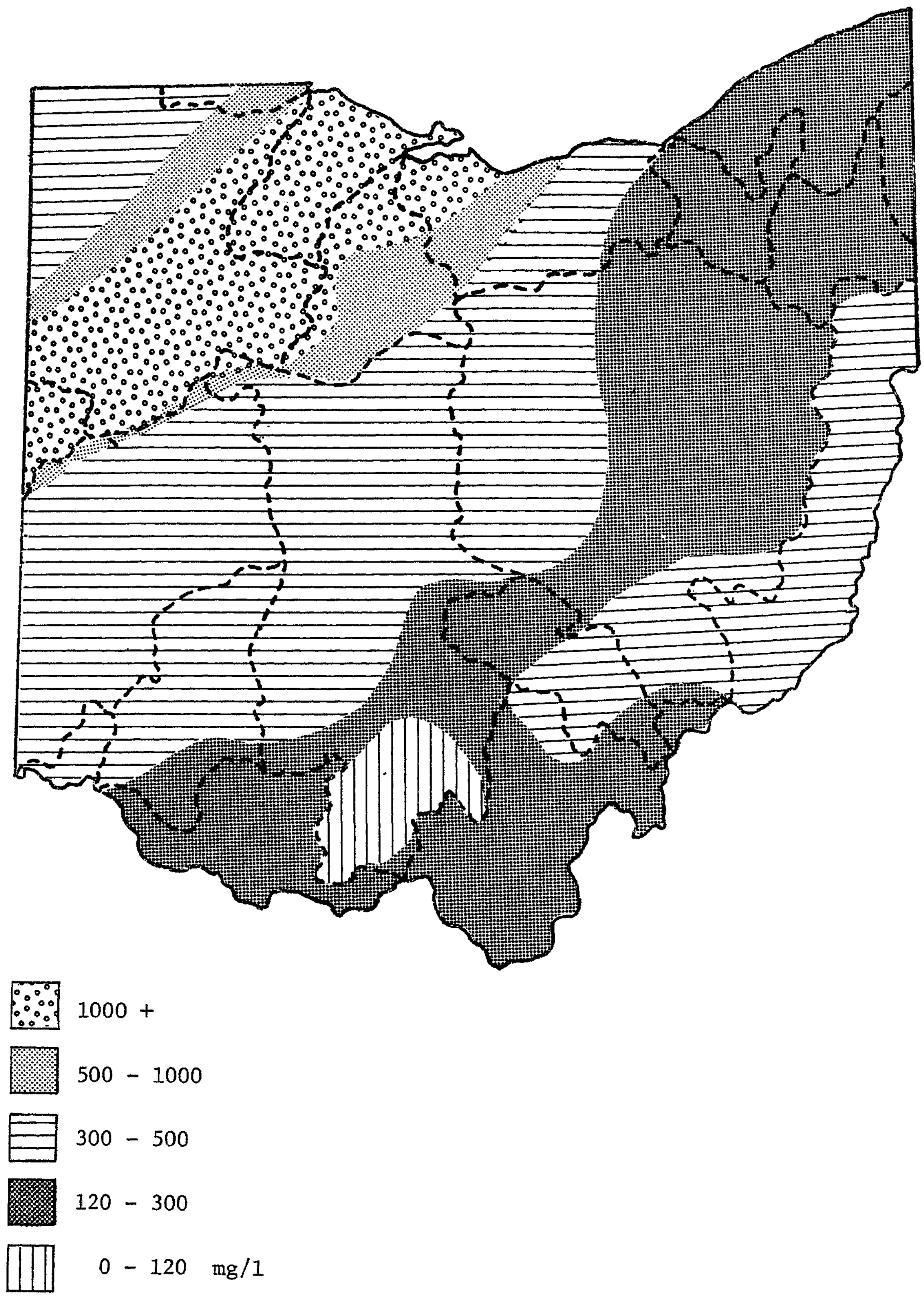



FIGURE 6-4. HARDNESS CONCENTRATIONS IN GROUND WATER IN OHIO

Using low-flow data, it was not possible to construct maps that would adequately show the variability of chloride and sulfate in shallow ground-water because of widespread contamination by municipal wastes, oil-field brine, acid-mine drainage, and other industrial effluents. For example, downstream from every major municipality, both chloride and sulfate concentrations increase dramatically.

This investigation is preliminary, which indicates that much more work needs to be done. Examples include statistical studies relating recharge rates more closely with flow ratios and flow-duration curves. Furthermore, similar investigations that use different techniques should be conducted in smaller basins to support or reject our interpretations.

In addition, the method of determination of shallow ground-water quality by means of low-flow stream data warrants further investigation. If the assumptions are valid, low-flow chemical data will provide a powerful tool not only for estimating regional ground-water quality, but also the effects of contamination.

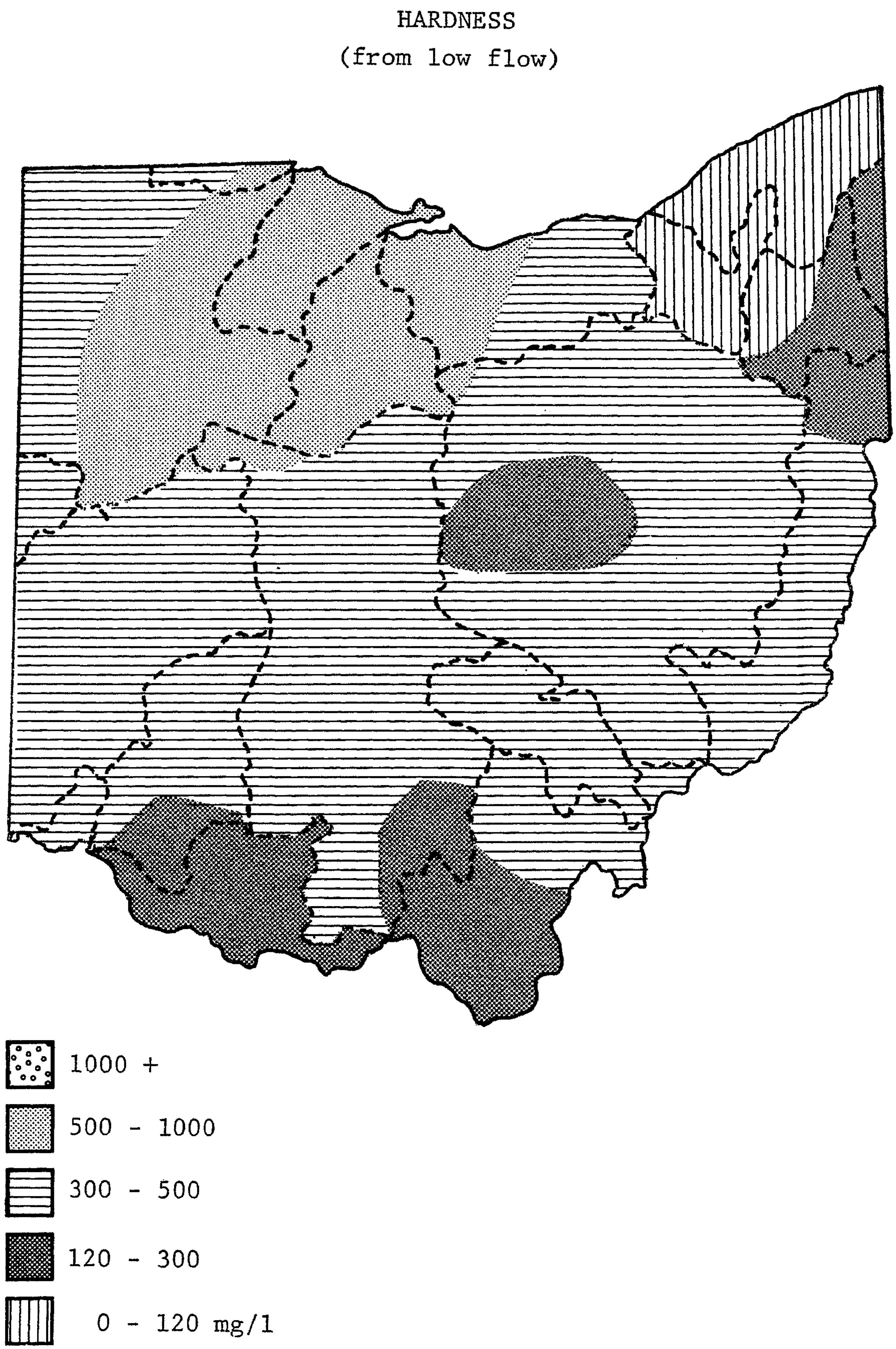



FIGURE 6-5. HARDNESS CONCENTRATIONS IN OHIO STREAMS DURING LOW FLOW

CHLORIDE

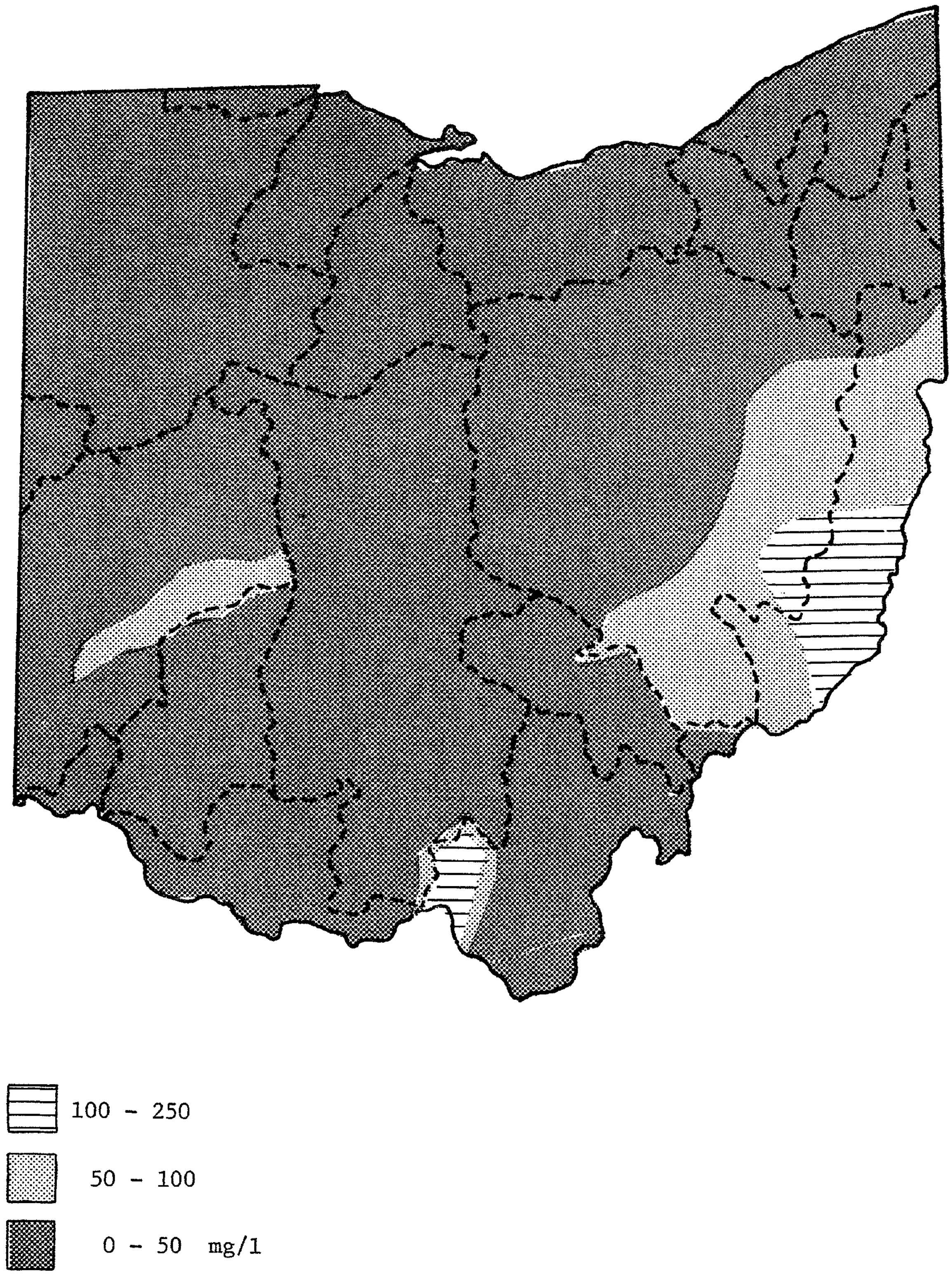



FIGURE 6-6. CHLORIDE CONCENTRATIONS IN GROUND WATER IN OHIO

SULFATE

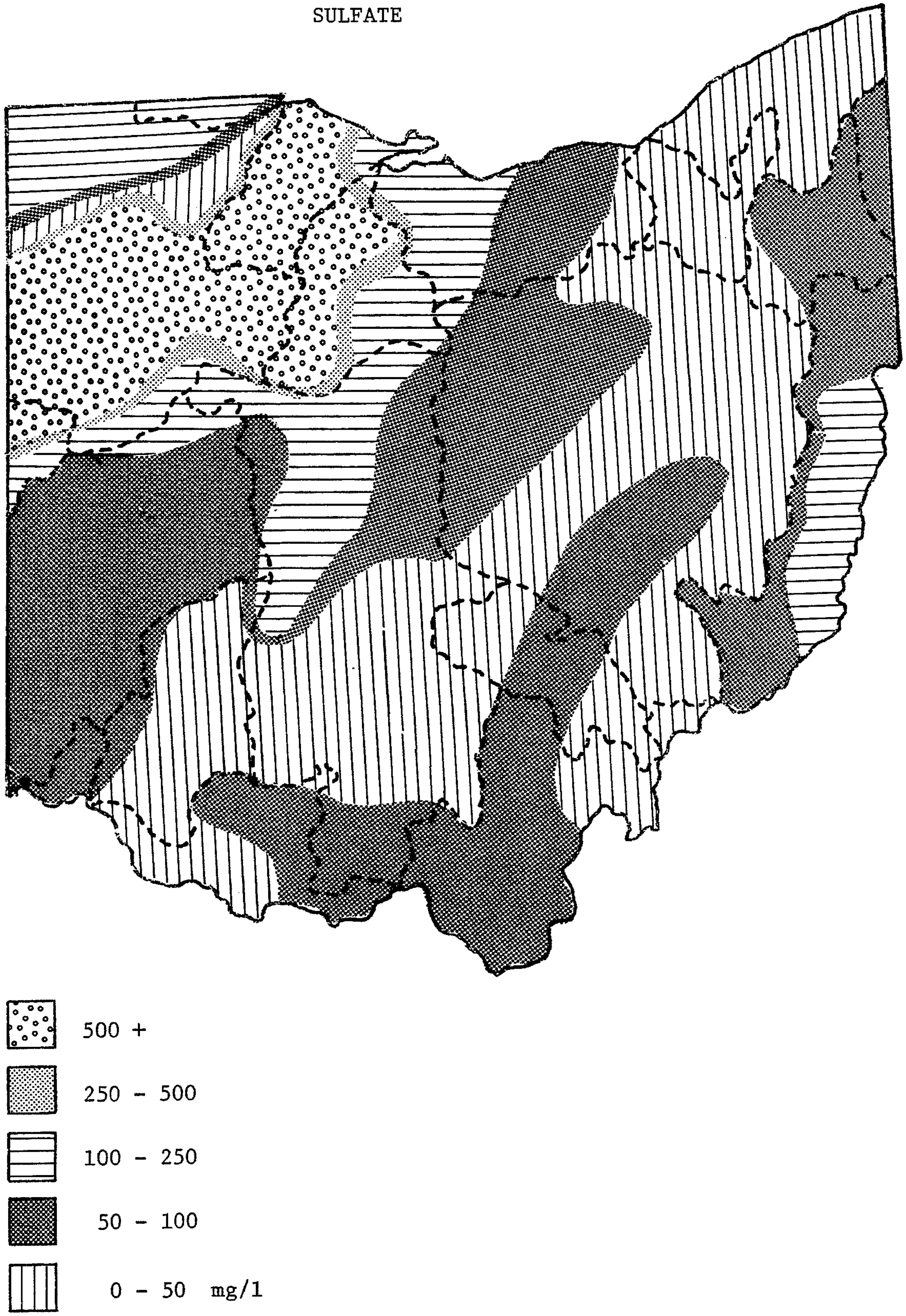




FIGURE 6-7. SULFATE CONCENTRATIONS IN GROUND WATER IN OHIO

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APPENDIX

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C********** QUARTIO ************************
C       THIS PROGRAM PLOTS TWO CHOSEN PARAMETERS AGAINST EACH OTHER AND
C       CALCULATES THE 2 REGRESSION EQUATIONS AND THE COEFFICIENT OF
C       CORRELATION
        DIMENSION HEAD(20), CONST(2,400), PARAM(366,19)
        DIMENSION R(19,19)
        DIMENSION LABEL(19)
        INTEGER*4 CONST
        DATA LABEL(1)/'QCFS'/,LABEL(2)/'TEMP'/,LABEL(3)/'COND'/,LABEL(4)/'
       1 PH '/,LABEL(5)/' SI '/,LABEL(6)/' CA '/,LABEL(7)/' MG '/,LABEL(8)
       2/' NA '/,LABEL(9)/'  K '/,LABEL(10)/'HCO3'/,LABEL(11)/' SO4'/,LABE
       3L(12)/' CL '/,LABEL(13)/'  F '/,LABEL(14)/' NO3'/,LABEL(15)/' DS '
       4/,LABEL(16)/'HARD'/,LABEL(17)/' FE '/,LABEL(18)/' MN '/,LABEL(19)/
       5'QLOG'/
        DATA THRESH/0.9/
C       THE CHEMICAL PARAMETERS AND THEIR CORRESPONDING NUMBERS ARE
C       DISCHARGE-1, TEMPERATURE-2, SPECIFIC CONDUCTANCE-3, PH-4, SILICON-
C       CALCIUM-6, MAGNESIUM-7, SODIUM-8, POTASSIUM-9, BICARBONATE-10,
C       SULFATE-11, CHLORIDE-12, FLOURIDE-13,NITRATE-14,DISSOLVED SOLIDS-1
C       HARDNESS-16, IRON-17, MANGANESE-18.
C       THE CHEMICAL DATA ARE ENTERED AS FOLLOWS- Q IN COLS 1-5 RIGHT
C       JUSTIFIED. THIS MUST BE INSTANTANEOUS DISCHARGE. TEMP IN COLS 6-9,
C       USE DECIMAL PT AND ONE PLACE TO THE RIGHT OF IT. CONDUCTANCE IN CO
C       10-13, RIGHT JUSTIFIED (RJ), PH IN COLS 14-17, WITH A DEC PT & ONE
C       PLACE TO THE RIGHT OF IT. SI IN COLS 18-21, DEC PT & ONE PLACE TO
C       THE RIGHT. CA IN COLS 22-25 RJ, MAGNESIUM IN COLS 26-28 RJ. NA IN
C       COLS 29-32 RJ. K IN COLS 33-36 RJ. BICARBONATE IN COLS 37-40 RJ.
C       SULFATE IN COLS 41-44 RJ. CL IN COLS 45-48 RJ. F IN COLS 49-51,DEC
C       PT & ONE PLACE AFTER. NO3 IN COLS 52-56, DEC PT AND ONE PLACE AFTE
C       DISSOLVED SOLIDS IN COLS57-60 RJ. HARDNESS IN COLS 61-64 RJ. IRON
C       GIVEN IN MICROGRAMS/LITER IT SHOULD BE CONVERTED TO MILLIGRAMS/LIT
C       BY DIVIDING BY 1000. IT IS IN COLS 65-69 WITH A DEC PT AND TWO
C       PLACES AFTER. MANGANESE SHOULD SIMILARLY BE PUT INTO MILLIGRAMS/
C       LITER AND PUT INTO COLS 70-74 WITH A DEC PT AND AND 2 PLACES AFTER
C       IT. ALL MISSING VALUES ARE ENTERED WITH  A -1.
C       THE LOG OF Q IS # 19 AND IS CALCULATED WITHIN THE PROGRAM
        INTEGER*4 CDTYPE(4),CARD(20),TYPE,XNAME,YNAME
        DATA CDTYPE/'DATA','RELA','RISO','RSUS'/
C   CARD-TYPE SYSTEM TO RECOGNIZE INPUT CARDS AND BRANCH ACCORDINGLY.
        CALL REREAD
  100   CONTINUE
        READ(5,306,END=300) CARD
  306   FORMAT(20A4)
        WRITE(6,307) CARD
  307   FORMAT(//,1X,20A4)
        READ(99,305) TYPE
  305   FORMAT(T15,A4)
        DO 301 I=1,4
        IF(TYPE.EQ.CDTYPE(I)) GO TO 302
  301   CONTINUE
        WRITE(6,108)
  108   FORMAT(' THE INPUT CARD PRINTED ABOVE IS NOT ONE OF THE ',
       X'ALLOWABLE STATEMENTS.'/,' THIS RUN IS THEREFORE ABORTED.')
        STOP
  302   CONTINUE
        GO TO (401,402,403,404),I
C
  401   CONTINUE
C   READ CHEMICAL DATA CARD DECK.
        CALL NORERD
C       READ IN THE HEADING
        READ (5,6) HEAD
C       READ IN THE # OF ANALYSES (QUALITY DATA CARDS)
        READ (5,9) NUMANL
C       READ IN CHEMICAL PARAMETERS
        DO 1 I=1,NUMANL
        READ (5,10) (PARAM(I,J),J=1,18)
        DO 1 K=1,18
```

```
      IF((PARAM(I,K)).LT.0.0) PARAM(I,K)=-1.0
 1    CONTINUE
C     COMPUTING LOG OF Q
      DO 3 I=1,NUMANL
      IF(PARAM(I,1).LE.0.0) GO TO 2
      PARAM(I,19)=ALOG10(PARAM(I,1))
      IF(PARAM(I,19).EQ.-1.0) PARAM(I,19)=-1.000001
      GO TO 3
 2    PARAM(I,19)=-1.
 3    CONTINUE
      CALL REREAD
      GO TO 100
C
 402  CONTINUE
C  CHANGE THE CORRELATION COEFFICIENT PLOT THRESHOLD TO (X.XX).
      READ(99,310) THRESH
 310  FORMAT(T55,F3.2)
      GO TO 100
C
 403  CONTINUE
C  PLOT ALL COMPARISONS WHOSE CORRELATION COEFFICIENT EXCEEDS THE THRESH
      CALL CORREL(NUMANL,PARAM,LABEL,R)
      DO 1000 I=1,19
      DO 101 J=1,19
      IF(J.LE.I) GO TO 101
      IF(R(I,J).EQ.-1.) GO TO 101
      IF(ABS(R(I,J)).GT.THRESH) CALL GRAPH(HEAD,NUMANL,I,J,LABEL,PARAM)
 101  CONTINUE
 1000  CONTINUE
      GO TO 100
C
 404  CONTINUE
C  PLOT (XXXX) VERSUS (YYYY).
      READ(99,311) XNAME,YNAME
 311  FORMAT(T7,A4,T21,A4)
C
C  FOR SPECIFICALLY REQUESTED PLOTS....
      DO 200 L=1,19
      IF(XNAME.EQ.LABEL(L)) GO TO 201
 200  CONTINUE
      WRITE(6,202) XNAME
 202  FORMAT(' X VARIABLE NAME ''',A4,''' IS NOT ONE OF THE '
     X,'ALLOWED NAMES. THE ABOVE CARD WILL BE IGNORED.')
      GO TO 100
 201  CONTINUE
      I=L
      DO 203 L=1,19
      IF(YNAME.EQ.LABEL(L)) GO TO 204
 203  CONTINUE
      WRITE(6,205) YNAME
 205  FORMAT(' Y VARIABLE NAME ''',A4,''' IS NOT ONE OF THE '
     X,'ALLOWED NAMES. THE ABOVE CARD WILL BE IGNORED.')
      GO TO 100
 204  CONTINUE
      J=L
      CALL GRAPH(HEAD,NUMANL,I,J,LABEL,PARAM)
C
      GO TO 100
C
 300  CONTINUE
      STOP
C
 6    FORMAT (20A4)
 9    FORMAT (I3)
 10   FORMAT (F5.0,F4.1,F4.0,2F4.1,F4.0,F3.0,5F4.0,F3.1,F5.1,2F4.0,2F5.2
     1)
      END
      SUBROUTINE GRAPH (HEAD,NUMANL,IN,JN,LABEL,PARAM)
```

```
C     HEAD IS AN ARRAY CONTAINING A HEADING (MAXIMUM OF 80 CHARACTERS)
C     NUMANL IS THE INTEGER NUMBER OF DATA POINTS
C     THE ARRAYS X AND Y CONTAIN THE COORDINATES OF THE NUMANL DATA
C  POINTS.
C     XO, YO, ARE THE REAL COORDINATES OF THE LOWER LEFT CORNER OF THE
C      GRAPH
C     DX AND DY ARE THE NUMBER OF UNITS/INCH ALONG THE X AND Y AXES
      DIMENSION GRAF(76,51), RLABEL(6), CLABEL(6), X(366), Y(366)
      DIMENSION HEAD(20)
      DIMENSION LABEL(19),PARAM(366,19)
      INTEGER XNAME,YNAME
      DATA HORIZO,VERT,PLUS,BLANK,EX,AST/'-','|','+',' ','X','*'/
C     THIS SECTION FINDS THE MAXIMA AND MINIMA AND CONSTRUCTS THE SCALE
      XMAX=0.0
      XMIN=10000.0
      YMAX=0.0
      YMIN=10000.0
      DO 4 I=1,NUMANL
      X(I)=PARAM(I,IN)
      Y(I)=PARAM(I,JN)
      IF(X(I).GE.XMAX) XMAX=X(I)
      IF(Y(I).GE.YMAX) YMAX=Y(I)
      IF((X(I).LT.XMIN).AND.(X(I).GE.0.0)) XMIN=X(I)
      IF((Y(I).LT.YMIN).AND.(Y(I).GE.0.0)) YMIN=Y(I)
 4    CONTINUE
      XO=XMIN
      YO=YMIN
      DX=(XMAX-XMIN)/5.0
      DY=(YMAX-YMIN)/5.0
      XNAME=LABEL(IN)
      YNAME=LABEL(JN)
      SUMX=0.0
      SUMY=0.0
      SUMXY=0.0
      SUMXSQ=0.0
      SUMYSQ=0.0
      WRITE (6,22) HEAD
C
C
C     THIS SECTION PRINTS UP BASIC GRAPH***
      DO 1 I=2,50
      GRAF(1,I)=VERT
      GRAF(76,I)=VERT
 1    CONTINUE
      DO 2 I=2,75
      GRAF(I,1)=HORIZO
      GRAF(I,51)=HORIZO
 2    CONTINUE
      DO 3 I=1,6
      IJ=1+(I-1)*10
      GRAF(1,IJ)=PLUS
      GRAF(76,IJ)=PLUS
 3    CONTINUE
      DO 40 I=1,6
      IJ=1+(I-1)*15
      GRAF(IJ,1)=PLUS
      GRAF(IJ,51)=PLUS
 40    CONTINUE
      DO 5 I=2,75
      DO 5 J=2,50
      GRAF(I,J)=BLANK
 5    CONTINUE
C     **************************************************
C
C
C     CHECK HERE FOR VARIOUS ERRORS***
      IF(NUMANL.LT.1) GO TO 18
      IF((DX.LE.0.0).OR.(DY.LE.0.0)) GO TO 19
```

```
C      ****************************************************
C
C
C      CALCULATE REGRESSION
       IMARK=0
       MARK=NUMANL
       DO 7  I=1,NUMANL
       IF((X(I).NE.-1.0).AND.(Y(I).NE.-1.0))  GO TO 6
       MARK=MARK-1
       IMARK=IMARK+1
       GO TO 7
  6    SUMX=X(I)+SUMX
       SUMY=Y(I)+SUMY
       SUMXSQ=(X(I))**2+SUMXSQ
       SUMYSQ=(Y(I))**2+SUMYSQ
       SUMXY=X(I)*Y(I)+SUMXY
  7    CONTINUE
       NEW=MARK
       DENOM=NEW*SUMXSQ-SUMX**2
       IF(DENOM.EQ.0.0)  GO TO 17
       A=(SUMXSQ*SUMY-SUMX*SUMXY)/DENOM
       B=(NEW*SUMXY-SUMX*SUMY)/DENOM
C      ...AND STORE IN THE GRAPH
       DO 8  IX=2,75
       XVALU=(IX-1.0)*DX/15.0+XO
       YVALU=A+B*XVALU
       IY=(YVALU-YO)*10./DY+0.5
       IF((IY.GT.51).OR.(IY.LT.1))  GO TO 8
       JY=52-IY
       GRAF(IX,JY)=AST
  8    CONTINUE
       DENMP=NEW*SUMYSQ-SUMY**2
       IF(DENMP.EQ.0.0)  GO TO 17
       AP=(SUMYSQ*SUMX-SUMY*SUMXY)/DENMP
       BP=(NEW*SUMXY-SUMX*SUMY)/DENMP
       DO 9  JY=1,51
       IY=52-JY
       YVALU=(IY-1.0)*DY/10.+YO
       XVALU=AP+BP*YVALU
       IX=(XVALU-XO)*15.0/DX+0.5
       IF((IX.GT.76).OR.(IX.LT.1))  GO TO 9
       GRAF(IX,JY)=PLUS
  9    CONTINUE
       R=SQRT(ABS(B*BP))*ABS(B)/B
C      ****************************************************
C
C
C      PLOTTING THE DATA POINTS***
 10    KOUNT=0
       DO 12  I=1,NUMANL
       ICOLX=(X(I)-XO)*15.0/DX+0.5
       IROWY=(Y(I)-YO)*10./DY+0.5
       JCOLX=ICOLX+1
       JROWY=51-IROWY
       IF(((JCOLX.LE.76).AND.(JCOLX.GE.1)).AND.((JROWY.LE.51).AND.(JROWY.
      1GE.1)))  GO TO 11
C      IN CASE PT IS OFF GRAPH:
       KOUNT=KOUNT+1
       GO TO 12
 11    GRAF(JCOLX,JROWY)=EX
C      ****************************************************
C
C
C      MAKING LABELS AND PRINTING OUT GRAPH***
 12    CONTINUE
       DO 13  I=1,6
       CLABEL(I)=XO+DX*(I-1)
       RLABEL(I)=YO+DY*(6-I)
```

```
 13   CONTINUE
      DO 16 I=1,51
      DO 14 K=1,6
      IF(I.EQ.(1+10*(K-1))) GO TO 15
 14   CONTINUE
      WRITE (6,23) (GRAF(J,I),J=1,76)
      GO TO 16
 15   WRITE (6,24) RLABEL(K),(GRAF(J,I),J=1,76)
 16   CONTINUE
      WRITE (6,25) (CLABEL(I),I=1,6)
      WRITE (6,26) YNAME,XNAME
C     ***************************************************
C
C
C     PRINTING OUT:
C     # OF PTS OFF GRAPH
      KOUNT=KOUNT-IMARK
      WRITE (6,27) KOUNT
      WRITE (6,28) IMARK
C     THE REGRESSION EQUATION,
      IF(DENOM.EQ.0.0) GO TO 21
      IF(DENMP.EQ.0.0) GO TO 21
      WRITE (6,29) A,B
      WRITE (6,30) AP,BP
      WRITE (6,31) R
      GO TO 21
C     VARIOUS ERROR MESSAGES,
 17   WRITE (6,32)
      GO TO 10
 18   WRITE (6,33) NUMANL
      GO TO 21
 19   WRITE (6,34) DX,DY
      GO TO 21
C     AND A TABLE OF X & Y VALUES
 21   WRITE (6,37)
      WRITE(6,38)(XNAME,YNAME,J=1,4)
 38   FORMAT('0',4(1X,A4,6X,A4,14X),/)
      WRITE(6,39)(X(I),Y(I),I=1,NUMANL)
 39   FORMAT(4(1X,F7.2,3X,F7.2,11X))
      RETURN
C
 22   FORMAT ('1',20A4)
 23   FORMAT (' ',T23,76A1)
 24   FORMAT (' ',T10,F10.2,T23,76A1)
 25   FORMAT ('0',T17,6(F10.2,5X))
 26   FORMAT ('0',A4,2X,'VERSUS',2X,A4,/)
 27   FORMAT (' ','THE NUMBER OF POINTS OFF THE GRAPH AREA=',I4)
 28   FORMAT (' ',T10,'# OF MISSING DATA POINTS:',I4)
 29   FORMAT (' ',T30,'Y=',F12.4,' +',F12.4,'*X')
 30   FORMAT (' ',T30,'X=',F12.4,' +',F12.4,'*Y')
 31   FORMAT (' ',T10,'R=',F8.2)
 32   FORMAT ('0','REGRESSION CANNOT BE CALCULATED.')
 33   FORMAT ('0','NUMANL LESS THAN 1. NUMANL=',I4)
 34   FORMAT ('0','MISTAKE DX OR DY NOT POSITIVE. DX=',F10.2,' DY=',F10.
     12)
 37   FORMAT ('1',T50,'TABLE OF X AND Y VALUES')
      END
      SUBROUTINE CORREL(NUMANL,PARAM,LABEL,R)
C  THIS SUBROUTINE COMPUTES ALL CORRELATION COEFFICIENTS
C    AMONG THE PARAMETERS.
      DIMENSION PARAM(366,19),R(19,19),LABEL(19)
       LOGICAL*1 ABUF(132),BLANK(5)/5*' '/
      LOGICAL*1 MINUS1(5)/'-','1','.','0','0'/
      LOGICAL FRSTIM/.TRUE./
      IF(.NOT.FRSTIM) GO TO 100
      FRSTIM=.FALSE.
       DEFINE FILE 1(1,132,L,IREC)
      CALL CORBUF(1)
```

```
 100   CONTINUE
       WRITE(6,6)
 6     FORMAT(1H1,T50,'CORRELATION COEFFICIENT MATRIX',/)
       WRITE(6,7) LABEL
 7     FORMAT(8X,19(1X,A4,1X))
       DO 1 I=1,19
       DO 2 J=1,19
       SUMX=0.
       SUMY=0.
       SUMXY=0.
       SUMXSQ=0.
       SUMYSQ=0.
       MARK=NUMANL
       DO 3 K=1,NUMANL
       X=PARAM(K,I)
       Y=PARAM(K,J)
       IF(X.NE.-1.0.AND.Y.NE.-1.0) GO TO 60
       MARK=MARK-1
       GO TO 3
 60    CONTINUE
       SUMX=SUMX+X
       SUMY=SUMY+Y
       SUMXSQ=SUMXSQ+X*X
       SUMYSQ=SUMYSQ+Y*Y
       SUMXY=SUMXY+X*Y
 3     CONTINUE
       DENOM=MARK*SUMXSQ-SUMX*SUMX
       IF(DENOM.EQ.0.0) GO TO 17
       B=(MARK*SUMXY-SUMX*SUMY)/DENOM
       DENMP=MARK*SUMYSQ-SUMY*SUMY
       IF(DENMP.EQ.0.0) GO TO 17
       BP=(MARK*SUMXY-SUMX*SUMY)/DENMP
       IF(B.EQ.0.) GO TO 17
       R(I,J)=SQRT(ABS(B*BP))*ABS(B)/B
       GO TO 2
 17    CONTINUE
       R(I,J)=-1.
 2     CONTINUE
C  CONVERT PRINT LINE TO 'A' FORMAT.
       WRITE(1'1,50) LABEL(I),(R(I,J),J=1,19)
 50    FORMAT(1X,A4,1X,19(1X,F5.2))
       READ(1'1)ABUF
C  REPLACE '-1.00' WITH BLANKS WHEREVER IT OCCURS.
 52    CONTINUE
       CALL CMPARE(MINUS1(1),5,ABUF(1),132,IND)
       IF(IND.EQ.0) GO TO 51
       CALL INSERT(BLANK(1),0,ABUF(IND),5)
       GO TO 52
 51    CONTINUE
       WRITE(6,10) ABUF
 10    FORMAT('0',132A1)
 1     CONTINUE
       RETURN
       END
C********** STRHYDRO **************************
C THIS PROGRAM READS DAILY DISCHARGE AND PRINTS CURVE FOR EACH WATER YEA
C BY JOHN B MCKEON AND JACK TULLER 1/30/75
       INTEGER PLUS,DOT,BLANK
       DIMENSION STA(16),MON(365),MAP(120),DIS(365)
       DIMENSION MONSUB(12),MONTH(12)
       REAL MDIS,LMIN,LMAX
       DATA BLANK/'    '/,PLUS/'++++'/,DOT/'....'/
       DATA MON/365*'    '/
C
C      THIS SECTION MAKES THE MONTHLY LABELS
C
       DATA MONSUB/15,46,76,107,138,166,197,227,258,288,319,350/
       INTEGER DOTSUB(12)/31,61,92,123,151,182,212,243,273,304,335,365/
```

```
      DATA MONTH/'OCT ','NOV ','DEC ','JAN ','FEB ','MAR ','APR ',
     X'MAY ','JUN ','JUL ','AUG ','SEP '/
      DO 500 I=1,12
      MON(MONSUB(I))=MONTH(I)
      MON(DOTSUB(I))=DOT
  500 CONTINUE
C     READS THE STATION NAME AND NUMBER AND THE AREA OF THE BASIN
C
      READ(5,100) STA,DRA,N
  100 FORMAT(16A4,2X,F8.0,3X,I3)
      IF(N.NE.365) GO TO 7
C
C     READS IN DISCHARGE VALUES FROM CARDS
C
      READ(5,110) DIS
  110 FORMAT(10(F8.0))
      NOFLOW=0
      NMISS=0
      DMAX=0.0
      DO 1 I=1,365
      IF(DIS(I).GT.DMAX)DMAX=DIS(I)
      IF(DIS(I).EQ.0.)NOFLOW=NOFLOW+1
      IF(DIS(I).EQ.-1.) NMISS=NMISS+1
    1 CONTINUE
      IF(DMAX/DRA.GT.100.0) GO TO 9
C
C****************************************
C
C     WRITES OUT HYDROGRAPH
C
C     FIRST, STATION NUMBER AND DRAINAGE AREA
      WRITE(6,200) STA,DRA
  200 FORMAT('1',40X,16A4,2X,F8.2,2X,'SQ.MI')
      IF(NOFLOW.GT.0) WRITE(6,2) NOFLOW
    2 FORMAT(' NOTE - THERE ARE ',I3,' DAYS OF NO FLOW.')
      IF(NMISS.GT.0) WRITE(6,3) NMISS
    3 FORMAT(' NOTE - THERE ARE ',I3,' DAYS OF MISSING DATA.')
C     THEN LABELS
      WRITE(6,210)
  210 FORMAT('0','MONTH',53X,'DISCHARGE, IN CFS')
C     THIS IS THE LOG SCALE OF THE HYDROGRAPH
      WRITE(6,220)
  220 FORMAT('0',4X,'.1',18X,'1',18X,'10'     ,17X,'100',15X,'1,000',14X,
     *'10,000',13X,'100,000')
      WRITE(6,230)
  230 FORMAT('0',4X,'*',6(19('+'),'*'))
      DO 300 I=1,365
      DO 250 J=1,119
C
C     MAP= ONE OUTPUT LINE OF THE HYDROGRAPH
C     THIS SECTION CREATES BASIC GRAPH OUTLINE
C
  250 MAP(J)=BLANK
      MAP(120)=PLUS
      IF(MON(I).NE.DOT)GO TO 270
      IF(I.EQ.365) GO TO 270
      DO 260 KI=2,118,2
  260 MAP(KI)=DOT
  270 CONTINUE
      IF(I/2.-I/2) 271,271,274
  271 MAP(40)=DOT
      MAP(80)=DOT
  274 CONTINUE
C
C     THIS SECTION ASSIGNS THE DISCHARGE VALUE A POINT ON THE GRAPH AND
C     OUTPUTS THAT DAY
      IF(DIS(I).LE..1) GO TO 275
C     ON THE GRAPH 20 SPACES= 1 LOG CYCLE AND THE LINE STARTS AT -1 LOG
```

```
C       CYCLE
        DLOG=20.*ALOG10(        DIS(I) )+20.
C       THIS STATEMENT ''ROUNDS OFF'' VALUES TO THE NEAREST PRINT POSITION
        INDX=DLOG+0.5
        IF( INDX.LT.1  .OR.  INDX.GT.120)  GO TO 275
        MAP( INDX)=PLUS
  275   WRITE(6,280)  MON(I),MAP,DIS(I)
  280   FORMAT(' ',    A4,    '+',120A1,F7.1)
  300   CONTINUE
C
C       ...AND SOME FINAL LABELS
C
        WRITE(6,330)
        WRITE(6,220)
  330   FORMAT(' ',4X,'*',6(19('+'),'*'))
C
C THIS PART OF THE PROGRAM CALCULATES AND PRINTS OUT THE SUMMARY STATIST
C
C       LMIN= MINIMUM DISCHARGE
C       LMAX= MAXIMUM DISCHARGE
C       TOQUAN= TOTAL DISCHARGE IN A YEAR
C       MDIS= MEAN DISCHARGE
        LMIN=100000.
        LMAX=.0
        TOTDIS=.0
        DO 350 I=1,365
        TOTDIS=TOTDIS+DIS(I)
        IF(DIS(I).LT.LMIN) LMIN=DIS(I)
        IF(DIS(I).GT.LMAX) LMAX=DIS(I)
  350   CONTINUE
        TOQUAN=86400.*TOTDIS
        MDIS=TOTDIS/365.
        WRITE(6,215)
  215   FORMAT('0')
        WRITE(6,360)TOQUAN
 360    FORMAT('0','TOTAL DISCHARGE FOR THE WATER YEAR',3X,E10.3,1X,'CF')
        WRITE(6,370) LMIN
  370   FORMAT('0','MINIMUM DISCHARGE',22X,F8.2,1X,'CFS')
        WRITE(6,380) MDIS
  380   FORMAT('0','MEAN DISCHARGE',25X,F8.2,1X,'CFS')
        WRITE(6,390) LMAX
  390   FORMAT('0','MAXIMUM DISCHARGE',22X,F8.2,1X,'CFS')
        TDISMI=TOQUAN/DRA
        WRITE(6,215)
        WRITE(6,395)  TDISMI
 395    FORMAT('0','TOTAL DISCHARGE/YR/BASIN AREA',8X,E10.3,1X,'CF/SQ.MI')
C
C THIS PART SETS UP AND PRINTS THE DISCHARGE/AREA OF DRAINAGE BASIN CURV
C
        WRITE(6,200) STA,DRA
C       LABELS:
        WRITE(6,600)
  600   FORMAT('0','MONTH',42X,'DISCHARGE/AREA OF DRAINAGE BASIN,',
       *' CFS/SQ.MI')
C       LOG SCALE FOR GRAPH:
        WRITE(6,610)
 610    FORMAT('0',4X,'.01',27X,'.10',27X,'1.0',27X,'10.0',26X,'100.0')
        WRITE(6,620)
 620    FORMAT('0',4X,4('*',29('+')),'*')
C
C       THIS SECTION CREATES THE BASIC GRAPH OUTLINE
C
        DO 650 I=1,365
        DO 630 J=1,119
  630   MAP(J)=BLANK
        MAP(120)=PLUS
        IF(MON(I).NE.DOT) GO TO 635
        IF(I.EQ.365) GO TO 635
```

```
      DO 632 MI=2,118,2
  632 MAP(MI)=DOT
  635 CONTINUE
      IF(I/2.-I/2) 636,636,640
636   MAP(30)=DOT
      MAP(60)=DOT
      MAP(90)=DOT
  640 CONTINUE
C
C     THIS SECTION ASSIGNS NORMALIZED DISCHARGE VALUE A POINT ON THE
C     GRAPH AND OUTPUTS THAT DAY
      Y=DIS(I)/DRA
      IF(Y.LE..01)GO TO 645
C
C     THIS EXPANDED SCALE HAS 1 LOG CYCLE= 30 SPACES AND STARTS AT -2
C     LOG CYCLES
      X=30. * ALOG10(Y)+60.
      IF(X.GT.120.5) GO TO 645
C     THIS ''ROUNDS OFF'' VALUES TO THE NEAREST PRINT POSITION
      INDX=X+0.5
      IF(INDX.LT.1 .OR. INDX.GT.120) GO TO 645
      MAP(INDX)=PLUS
  645 WRITE(6,280) MON(I),MAP,DIS(I)
  650 CONTINUE
      WRITE(6,621)
621   FORMAT(' ',4X,4('*',29('+')),'*')
      WRITE(6,610)
400   STOP
 7    WRITE(6,6) N
 6    FORMAT('0','***** ERROR *****  N IS ',I3,'.  THIS PROGRAM IS DESIG
     *NED FOR WATER YEARS OF 365 DAYS'/'0',' BEGINNING IN OCTOBER.  PLEA
     *SE USE ANOTHER PROGRAM FOR OTHER TYPES OF RECORDS.')
      STOP
 9    WRITE(6,8) DMAX,DRA
 8    FORMAT('0','***** ERROR *****  MAXIMUM DISCHARGE IS ',F10.0,'. DRA
     *INAGE AREA IS ',F8.2,'.  '/'0','            THE RATIO DISCHARGE/DRA
     *INAGE AREA EXCEEDS 100 CFS/SQ.MI.')
      STOP
      END
C********** QUALDUR ***********************
C     THIS PROGRAM PLOTS QUALITY DURATION CURVES FOR CHOSEN PARAMETERS
C     APRIL 1976
C     HEAD IS THE HEADING CARD WITH STATION NUMBER AND NAME
C     PARAM IS THE ARRAY THAT STORES THE CHEMICAL DATA
C     STORE IS THE ARRAY THAT COMPRESSES THE DATA SET, ELIMINATING GAPS
C     LABEL IS THE ARRAY OF THE  18 CONSTITUENT NAMES
C     PCT IS THE ARRAY OF THE % EXCEEDED OR EQUALLED FOR EACH CHEMICAL
C     READING
C     INDEX IS THE ARRAY THAT RECORDS THE CODE NUMBERS OF THE CHEMICAL
C     CONSTITUENTS FOR WHICH CURVES ARE DESIRED
C     THE CHEMICAL PARAMETERS AND THEIR CORRESPONDING NUMBERS ARE
C     DISCHARGE-1, TEMPERATURE-2, SPECIFIC CONDUCTANCE-3, PH-4, SILICON-
C     CALCIUM-6, MAGNESIUM-7, SODIUM-8, POTASSIUM-9, BICARBONATE-10,
C     SULFATE-11, CHLORIDE-12, FLOURIDE-13,NITRATE-14,DISSOLVED SOLIDS-1
C     HARDNESS-16, IRON-17, MANGANESE-18.
C     THE CHEMICAL DATA ARE ENTERED AS FOLLOWS- Q IN COLS 1-5 RIGHT
C     JUSTIFIED. THIS MUST BE INSTANTANEOUS DISCHARGE. TEMP IN COLS 6-9,
C     USE DECIMAL PT AND ONE PLACE TO THE RIGHT OF IT. CONDUCTANCE IN CO
C     10-13, RIGHT JUSTIFIED (RJ), PH IN COLS 14-17, WITH A DEC PT & ONE
C     PLACE TO THE RIGHT OF IT. SI IN COLS 18-21, DEC PT & ONE PLACE TO
C     THE RIGHT. CA IN COLS 22-25 RJ, MAGNESIUM IN COLS 26-28 RJ. NA IN
C     COLS 29-32 RJ. K IN COLS 33-36 RJ. BICARBONATE IN COLS 37-40 RJ.
C     SULFATE IN COLS 41-44 RJ. CL IN COLS 45-48 RJ. F IN COLS 49-51,DEC
C     PT & ONE PLACE AFTER. NO3 IN COLS 52-56, DEC PT AND ONE PLACE AFTE
C     DISSOLVED SOLIDS IN COLS57-60 RJ. HARDNESS IN COLS 61-64 RJ. IRON
C     GIVEN IN MICROGRAMS/LITER IT SHOULD BE CONVERTED TO MILLIGRAMS/LIT
C     BY DIVIDING BY 1000. IT IS IN COLS 65-69 WITH A DEC PT AND TWO
C     PLACES AFTER. MANGANESE SHOULD SIMILARLY BE PUT INTO MILLIGRAMS/
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```
C     LITER AND PUT INTO COLS 70-74 WITH A DEC PT AND AND 2 PLACES AFTER
C     IT. ALL MISSING VALUES ARE ENTERED WITH  A -1.
      INTEGER HEAD
      DIMENSION INDEX(18), PARAM(365,18), PRAM(367), STORE(365), LABEL(1
     18), PCT(367), HEAD(20)
      DATA LABEL(1)/'QCFS'/,LABEL(2)/'TEMP'/,LABEL(3)/'COND'/,LABEL(4)/'
     1 PH '/,LABEL(5)/' SI '/,LABEL(6)/' CA '/,LABEL(7)/' MG '/,LABEL(8)
     2/' NA '/,LABEL(9)/'  K '/,LABEL(10)/'HCO3'/,LABEL(11)/' SO4'/,LABE
     3L(12)/' CL '/,LABEL(13)/'  F '/,LABEL(14)/' NO3'/,LABEL(15)/' DS '
     4/,LABEL(16)/'HARD'/,LABEL(17)/' FE '/,LABEL(18)/' MN '/
C     READS HEADING
      READ (5,12) HEAD
C     READS NMCNST, THE NUMBER OF CONSTITUENTS ONE IS GOING TO REQUEST
C     QUALITY DURATION CURVES FOR. THIS WILL BE IN COLS 1-2 RJ OF THE DA
C     CARD (NO DEC PT)
      READ (5,13) NMCNST
C     THIS READS THE CODE NUMBERS OF THE PARAMETERS FOR WHICH DURATION
C     CURVES ARE DESIRED. EACH CODE NUMBER TAKES 2 COLS RJ, STARTING WIT
C     COLS 1-2, THEN COLS 3-4, ETC. EACH CODE NUMBER IS AN INTEGER WITH
C     DECIMAL PT.
      READ (5,14) (INDEX(I),I=1,NMCNST)
C     THIS READS NUMANL THE NUMBER OF ANALYSES IN THE DATA SET. THIS IS
C     COLS1-3 RJ WITH NO DEC PT ON THE DATA CARD
      READ (5,15) NUMANL
C     THIS READS IN ALL THE CHEMICAL INFORMATION OFF THE DATA CARDS
      DO 1 I=1,NUMANL
      READ (5,16) (PARAM(I,J),J=1,18)
  1   CONTINUE
      DO 11 IND=1,NMCNST
      M=(INDEX(IND))
C     THIS SECTION EXTRACTS THE MINIMUM AND MAXIMUM VALUES OF THE
C     PARAMETER AND CONSTRUCTS THE SCALE OF THE FLOW DURATION GRAPH
      PMAX=0.0
      PMIN=10000.0
      DO 2 I=1,NUMANL
      IF(PARAM(I,M).GT.PMAX) PMAX=PARAM(I,M)
      IF((PARAM(I,M).LT.PMIN).AND.(PARAM(I,M).GE.0.0)) PMIN=PARAM(I,M)
  2   CONTINUE
      XO=PMIN
      DX=(PMAX-PMIN)/5.0
C
C     THIS SECTION COMPRESSES THE DATA VALUES , REMOVING MISSING VALUES
      II=0
      DO 3 I=1,NUMANL
      IF(PARAM(I,M).LT.0.0) GO TO 3
      II=II+1
      STORE(II)=PARAM(I,M)
  3   CONTINUE
      IF(II.GT.0) GO TO 4
      WRITE (6,17) LABEL(M)
      GO TO 11
  4   DO 5 I=1,II
      PARAM(I,M)=STORE(I)
  5   CONTINUE
C
C     THIS SECTION CALCULATES % EQUALLED OR EXCEEDED FOR EACH PARAMETER
C     VALUE
      DO 6 I1=1,II
      PCT(I1)=0.0
  6   CONTINUE
      DO 7 I1=1,II
      DO 7 I2=1,II
      IF((PARAM(I2,M)).GE.(PARAM(I1,M))) PCT(I1)=PCT(I1)+100./II
  7   CONTINUE
      DO 8 I=1,II
      PRAM(I)=PARAM(I,M)
  8   CONTINUE
      IF(II.EQ.1) GO TO 10
```

```
C
C     THIS SECTION SORTS THE PARAMETER VALUES IN DESCENDING ORDER
      N=II-1
      DO 9 I=1,N
      K=I+1
      DO 9 J=K,II
      IF(PCT(I).GE.PCT(J)) GO TO 9
      HOLD1=PCT(I)
      PCT(I)=PCT(J)
      PCT(J)=HOLD1
      HOLD2=PRAM(I)
      PRAM(I)=PRAM(J)
      PRAM(J)=HOLD2
    9 CONTINUE
   10 CALL DURAT (PRAM,PCT,XO,DX,LABEL(M),II,HEAD)
C     OUTPUTTING A TABLE OF VALUES
      WRITE (6,120) (LABEL(M),J=1,4)
  120 FORMAT ('1',4(5X,A4,7X,'PCT',8X))
      WRITE (6,130) (PRAM(I),PCT(I),I=1,N)
  130 FORMAT (4(F10.3,3X,F7.3,8X),/)
   11 CONTINUE
      STOP
C
   12 FORMAT (20A4)
   13 FORMAT (I2)
   14 FORMAT (18I2)
   15 FORMAT (I3)
   16 FORMAT (F5.0,F4.1,F4.0,2F4.1,F4.0,F3.0,5F4.0,F3.1,F5.1,2F4.0,2F5.2
     1)
   17 FORMAT ('1','NO VALUES OF',A4)
      END
C     DURAT IS A SUBROUTINE THAT OUTPUTS A QUALITY DURATION CURVE
      SUBROUTINE DURAT (PRAM,PCT,XO,DX,LABEL,N,HEAD)
      INTEGER HEAD
      DIMENSION PRAM(N), PCT(N), PLOT(76,51), HEAD(20), GLAB(6)
      DATA HORIZO,VERT,BLANK,AST,DOT/'-','|',' ','*','.'
     1/
C     WRITING OUT THE HEADING
      WRITE (6,8) HEAD
C     PLOTTING UP THE BASIC GRAPH
      DO 1 I=1,76
      DO 1 J=1,51
      PLOT(I,J)=BLANK
    1 CONTINUE
      DO 2 I=2,50
      PLOT(1,I)=VERT
      PLOT(76,I)=VERT
      PLOT(16,I)=DOT
      PLOT(31,I)=DOT
      PLOT(46,I)=DOT
      PLOT(61,I)=DOT
    2 CONTINUE
      DO 3 I=2,75
      PLOT(I,1)=HORIZO
      PLOT(I,51)=HORIZO
      PLOT(I,11)=DOT
      PLOT(I,21)=DOT
      PLOT(I,31)=DOT
      PLOT(I,41)=DOT
    3 CONTINUE
      DO 4 I=1,N
C     BOTH X, THE PARAMETER AXIS AND Y, THE PCT AXIS ARE ARITHMETIC SCAL
C     THE SCALE ON THE PARAMETER AXIS HAS BEEN DETERMINED  FROM THE
C     RANGE OF THE DATA.
      IX=IFIX((PRAM(I)-XO)*15./DX+.5)+1
      IY=IFIX((100.-PCT(I))/2.+.5)+1
      PLOT(IX,IY)=AST
    4 CONTINUE
```

```
C       THIS CREATES THE BOTTOM LABELS
        DO 5 I=1,6
        GLAB(I)=(FLOAT(I-1))*DX+XO
 5      CONTINUE
C       OUTPUTTING THE GRAPH
        DO 6 I=1,51
        IJ=102-2*I
        WRITE (6,9) IJ,(PLOT(J,I),J=1,76)
 6      CONTINUE
        WRITE (6,10) GLAB
        WRITE (6,11)  LABEL
        RETURN
C
 8      FORMAT ('1',20A4,//)
 9      FORMAT (' ',I10,2X,76A1)
 10     FORMAT (' ',T7,6(F10.3,5X))
 11     FORMAT (' ',5X,'PERCENT',/,' ',43X,'CONCENTRATION OF:',A4)
        END
C********** VQUADUR ***********************
C       THIS PROGRAM PLOTS QUALITY DURATION CURVES FOR CHOSEN PARAMETERS
C       APRIL 1976
C       HEAD IS THE HEADING CARD WITH STATION NUMBER AND NAME
C       PARAM IS THE ARRAY THAT STORES THE CHEMICAL DATA
C       STORE IS THE ARRAY THAT COMPRESSES THE DATA SET, ELIMINATING GAPS
C       LABEL IS THE ARRAY OF THE  18 CONSTITUENT NAMES
C       PCT IS THE ARRAY OF THE % EXCEEDED OR EQUALLED FOR EACH CHEMICAL
C       READING
C       INDEX IS THE ARRAY THAT RECORDS THE CODE NUMBERS OF THE CHEMICAL
C       CONSTITUENTS FOR WHICH CURVES ARE DESIRED
C       THE CHEMICAL PARAMETERS AND THEIR CORRESPONDING NUMBERS ARE
C       DISCHARGE-1, TEMPERATURE-2, SPECIFIC CONDUCTANCE-3, PH-4, SILICON-
C       CALCIUM-6, MAGNESIUM-7, SODIUM-8, POTASSIUM-9, BICARBONATE-10,
C       SULFATE-11, CHLORIDE-12, FLOURIDE-13,NITRATE-14,DISSOLVED SOLIDS-1
C       HARDNESS-16, IRON-17, MANGANESE-18.
C       THE CHEMICAL DATA ARE ENTERED AS FOLLOWS- Q IN COLS 1-5 RIGHT
C       JUSTIFIED. THIS MUST BE INSTANTANEOUS DISCHARGE. TEMP IN COLS 6-9,
C       USE DECIMAL PT AND ONE PLACE TO THE RIGHT OF IT. CONDUCTANCE IN CO
C       10-13, RIGHT JUSTIFIED (RJ), PH IN COLS 14-17, WITH A DEC PT & ONE
C       PLACE TO THE RIGHT OF IT. SI IN COLS 18-21, DEC PT & ONE PLACE TO
C       THE RIGHT. CA IN COLS 22-25 RJ, MAGNESIUM IN COLS 26-28 RJ. NA IN
C       COLS 29-32 RJ. K IN COLS 33-36 RJ. BICARBONATE IN COLS 37-40 RJ.
C       SULFATE IN COLS 41-44 RJ. CL IN COLS 45-48 RJ. F IN COLS 49-51,DEC
C       PT & ONE PLACE AFTER. NO3 IN COLS 52-56, DEC PT AND ONE PLACE AFTE
C       DISSOLVED SOLIDS IN COLS57-60 RJ. HARDNESS IN COLS 61-64 RJ. IRON
C       GIVEN IN MICROGRAMS/LITER IT SHOULD BE CONVERTED TO MILLIGRAMS/LIT
C       BY DIVIDING BY 1000. IT IS IN COLS 65-69 WITH A DEC PT AND TWO
C       PLACES AFTER. MANGANESE SHOULD SIMILARLY BE PUT INTO MILLIGRAMS/
C       LITER AND PUT INTO COLS 70-74 WITH A DEC PT AND AND 2 PLACES AFTER
C       IT. ALL MISSING VALUES ARE ENTERED WITH  A -1.
        INTEGER HEAD
        DIMENSION INDEX(18), PARAM(365,18), PRAM(367), STORE(365), LABEL(1
       18), PCT(367), HEAD(20)
        DATA LABEL(1)/'QCFS'/,LABEL(2)/'TEMP'/,LABEL(3)/'COND'/,LABEL(4)/'
       1 PH '/,LABEL(5)/' SI '/,LABEL(6)/' CA '/,LABEL(7)/' MG '/,LABEL(8)
       2/' NA '/,LABEL(9)/'  K '/,LABEL(10)/'HCO3'/,LABEL(11)/' SO4'/,LABE
       3L(12)/' CL '/,LABEL(13)/'  F '/,LABEL(14)/' NO3'/,LABEL(15)/' DS '
       4/,LABEL(16)/'HARD'/,LABEL(17)/' FE '/,LABEL(18)/' MN '/
C       READS HEADING
        READ (5,12) HEAD
C       READS NMCNST, THE NUMBER OF CONSTITUENTS ONE IS GOING TO REQUEST
C       QUALITY DURATION CURVES FOR. THIS WILL BE IN COLS 1-2 RJ OF THE DA
C       CARD (NO DEC PT)
        READ (5,13) NMCNST
C       THIS READS THE CODE NUMBERS OF THE PARAMETERS FOR WHICH DURATION
C       CURVES ARE DESIRED. EACH CODE NUMBER TAKES 2 COLS RJ, STARTING WIT
C       COLS 1-2, THEN COLS 3-4, ETC. EACH CODE NUMBER IS AN INTEGER WITH
C       DECIMAL PT.
        READ (5,14) (INDEX(I),I=1,NMCNST)
```

```
C     THIS READS NUMANL THE NUMBER OF ANALYSES IN THE DATA SET. THIS IS
C     COLS1-3 RJ WITH NO DEC PT ON THE DATA CARD
      READ (5,15) NUMANL
C     THIS READS IN ALL THE CHEMICAL INFORMATION OFF THE DATA CARDS
      DO 1 I=1,NUMANL
      READ (5,16) (PARAM(I,J),J=1,18)
 1    CONTINUE
      DO 11 IND=1,NMCNST
      M=(INDEX(IND))
C     THIS SECTION EXTRACTS THE MINIMUM AND MAXIMUM VALUES OF THE
C     PARAMETER AND CONSTRUCTS THE SCALE OF THE FLOW DURATION GRAPH
      PMAX=0.0
      PMIN=10000.0
      DO 2 I=1,NUMANL
      IF(PARAM(I,M).GT.PMAX) PMAX=PARAM(I,M)
      IF((PARAM(I,M).LT.PMIN).AND.(PARAM(I,M).GE.0.0)) PMIN=PARAM(I,M)
 2    CONTINUE
      XO=PMIN
      DX=(PMAX-PMIN)/5.0
C
C     THIS SECTION COMPRESSES THE DATA VALUES , REMOVING MISSING VALUES
      II=0
      DO 3 I=1,NUMANL
      IF(PARAM(I,M).LT.0.0) GO TO 3
      II=II+1
      STORE(II)=PARAM(I,M)
 3    CONTINUE
      IF(II.GT.0) GO TO 4
      WRITE (6,17) LABEL(M)
      GO TO 11
 4    DO 5 I=1,II
      PARAM(I,M)=STORE(I)
 5    CONTINUE
C
C     THIS SECTION CALCULATES % EQUALLED OR EXCEEDED FOR EACH PARAMETER
C     VALUE
      DO 6 I1=1,II
      PCT(I1)=0.0
 6    CONTINUE
      DO 7 I1=1,II
      DO 7 I2=1,II
      IF((PARAM(I2,M)).GE.(PARAM(I1,M))) PCT(I1)=PCT(I1)+100./II
 7    CONTINUE
      DO 8 I=1,II
      PRAM(I)=PARAM(I,M)
 8    CONTINUE
      IF(II.EQ.1) GO TO 10
C
C     THIS SECTION SORTS THE PARAMETER VALUES IN DESCENDING ORDER
      N=II-1
      DO 9 I=1,N
      K=I+1
      DO 9 J=K,II
      IF(PCT(I).GE.PCT(J)) GO TO 9
      HOLD1=PCT(I)
      PCT(I)=PCT(J)
      PCT(J)=HOLD1
      HOLD2=PRAM(I)
      PRAM(I)=PRAM(J)
      PRAM(J)=HOLD2
 9    CONTINUE
 10   CONTINUE
      CALL DURATV(PRAM,PCT,LABEL(M),II,HEAD)
C     OUTPUTTING A TABLE OF VALUES
      WRITE (6,120) (LABEL(M),J=1,4)
 120  FORMAT ('1',4(4X,A4,6X,'PCT',8X))
      WRITE (6,130) (PRAM(I),PCT(I),I=1,N)
 130  FORMAT (4(F10.3,3X,F7.3,5X),/)
```

```
 11     CONTINUE
        STOP
C
 12     FORMAT (20A4)
 13     FORMAT ( I2)
 14     FORMAT ( 18I2)
 15     FORMAT ( I3)
 16     FORMAT (F5.0,F4.1,F4.0,2F4.1,F4.0,F3.0,5F4.0,F3.1,F5.1,2F4.0,2F5.2
       1)
 17     FORMAT ('1','NO VALUES OF',A4)
        END
C       DURATV IS A SUBROUTINE THAT OUTPUTS A QUALITY DURATION CURVE
C        ON THE VERSATEC PLOTTER.
        SUBROUTINE DURATV (PRAM,PCT,LABEL,N,HEAD)
        DIMENSION JLABEL(6)
        INTEGER HEAD
        DIMENSION PRAM(367), PCT(367),  HEAD(20)
        EQUIVALENCE(JLABEL(6),ILABEL)
        DATA JLABEL/'CONC','ENTR','ATIO','N OF',' :  ','    '/
        ILABEL=LABEL
        DATA LMASK/Z3333/
        CALL WINDOW(-0.5,7.5,-0.5,9.5)
        CALL PLOTS(0,0,0)
C   PLOT HEADING.
        CALL SYMBOL(0.1,9.0,0.10,HEAD,0.,80)
C   PLOT X AXIS.
        CALL SCALE(PRAM,7.0,N,1)
        CALL AXIS(0.0,0.0,JLABEL,-24,7.0,0.,PRAM(N+1),PRAM(N+2))
C   PLOT Y AXIS.
        CALL SCALE(PCT,8.0,N,1)
        PCT(N+2)=12.5
        CALL AXIS(0.0,0.0,'PERCENT',7,8.0,90.,PCT(N+1),PCT(N+2))
C   PLOT GRID.
        CALL GRID(0.0,0.0,7,1.0,8,1.0,LMASK)
C   PLOT DATA
        CALL NEWPEN(5)
        CALL LINE(PRAM,PCT,N,1,0)
C   END PLOT
        CALL PLOT(0.,0.,999)
        RETURN
C
        END
C********** FLOWDUR ***********************
C       THIS PROGRAM PRINTS OUT BOTH DISCHARGE AND NORMALIZED DISCHARGE FL
C       DURATION CURVES FOR ONE YEAR OF DISCHARGE RECORDS
C       MISSING VALUES ARE ENTERED AS A -1
C       HEAD IS THE STATION NUMBER AND TITLE
C       DRA IS THE DRAINAGE AREA
C       Q IS THE ARRAY OF THE DAILY DISCHARGE VALUES
C       PCT IS THE ARRAY OF THE % EXCEEDED OR EQUALLED FOR EACH DISCHARGE
C       HOLD IS AN ARRAY THAT COMPRESSES THE DISCHARGE VALUES, REMOVING GA
C       IN THE RECORD
C       N= # OF DAYS IN YEAR
        DIMENSION HEAD(16), Q(365), HOLD(365), PCT(365)
        DATA PCT/365*0.0/
C       READ IN TITLE AND DRAINAGE AREA :
        READ (5,6) HEAD,DRA,N
        IF(N.NE.365) GO TO 7
C       READ IN DISCHARGE VALUES,CHRONOLOGICALLY
        READ (5,8)  Q
        NEWN=0
        DMAX=0.0
        DO 1 I=1,365
C       TEST FOR MISSING VALUES:
        IF(Q(I).LE.0.0) GO TO 1
        NEWN=NEWN+1
        HOLD(NEWN)=Q(I)
        IF(Q(I).GT.DMAX)DMAX=Q(I)
```

```
 1    CONTINUE
      IF(DMAX/DRA.GT.100.0) GO TO 9
      DO 2 I=1,NEWN
C     RELOAD DISCHARGE ARRAY WITH GAPS REMOVED
      Q(I)=HOLD(I)
 2    CONTINUE
C
C     CALCULATE % EQUALLED OR EXCEEDED FOR EACH DISCHARGE VALUE:
      DO 3 I=1,NEWN
      DO 3 J=1,NEWN
      IF(Q(J).GE.Q(I)) PCT(I)=PCT(I)+100./NEWN
 3    CONTINUE
C
C     SORT DIS VALUES INTO ASCENDING ORDER, PCT VALUES INTO DESCENDING.
      NI=NEWN-1
      DO 4 I=1,NI
      K=I+1
      DO 4 J=K,NEWN
      IF(PCT(I).GE.PCT(J)) GO TO 4
      HOLD1=PCT(I)
      PCT(I)=PCT(J)
      PCT(J)=HOLD1
      HOLD2=Q(I)
      Q(I)=Q(J)
      Q(J)=HOLD2
 4    CONTINUE
      CALL FLDR (Q,PCT,NEWN,HEAD,DRA)
C
C     CONVERT DISCHARGE INTO NORMALIZED DISCHARGE
      DO 5 I=1,NEWN
      Q(I)=Q(I)/DRA
 5    CONTINUE
      CALL FLODUR (Q,PCT,NEWN,HEAD,DRA)
      STOP
 7    WRITE(6,60) N
 60   FORMAT('0','***** ERROR *****  N IS ',I3,'.  THIS PROGRAM IS DESIG
     *NED FOR WATER YEARS OF 365 DAYS'/'0',' BEGINNING IN OCTOBER.  PLEA
     *SE USE ANOTHER PROGRAM FOR OTHER TYPES OF RECORDS.')
      STOP
C
 9    WRITE(6,80)DMAX,DRA
 80   FORMAT('0','***** ERROR *****  MAXIMUM DISCHARGE IS ',F10.0,'. DRA
     *INAGE AREA IS ',F8.2,'.  '/'0','             THE RATIO DISCHARGE/DRA
     *INAGE AREA EXCEEDS 100 CFS/SQ.MI.')
      STOP
 6    FORMAT (16A4,2X,F8.0,3X,I3)
 8    FORMAT (10F8.0)
      END
C     FLDR IS A SUBROUTINE THAT PRINTS THE FLOW DURATION CURVE
C     OF THE DISCHARGE
      SUBROUTINE FLDR (Q,PCT,N,HEAD,DRA)
      DIMENSION Q(N), PCT(N), HEAD(16), PLOT(76,51), LABEL(6)
      REAL LABEL
      DATA HORIZO,VERT,BLANK,AST,DOT/'-','|',' ','*','.'
     1/
C
C     KOUNT KEEPS TRACK OF THE # OF PTS OFF THE GRAPH
      KOUNT=0
      WRITE (6,10) HEAD,DRA
C
C     CREATES BASIC GRAPH OUTLINE:
      DO 1 I=1,76
      DO 1 J=1,51
      PLOT(I,J)=BLANK
 1    CONTINUE
      DO 2 I=2,50
      PLOT(1,I)=VERT
      PLOT(76,I)=VERT
```

```
      PLOT(16,I)=DOT
      PLOT(31,I)=DOT
      PLOT(46,I)=DOT
      PLOT(61,I)=DOT
  2   CONTINUE
      DO 3 I=2,75
      PLOT(I,1)=HORIZO
      PLOT(I,51)=HORIZO
      PLOT(I,11)=DOT
      PLOT(I,21)=DOT
      PLOT(I,31)=DOT
      PLOT(I,41)=DOT
  3   CONTINUE
C
C     THIS SECTION ASSIGNS PTS ON GRAPH FOR DISCHARGE,PCT VALUES
      MIN=0
      DO 4 I=1,N
      IEDG=IFIX(ALOG10(Q(I)))-1
      IF(IEDG.LT.MIN) MIN=IEDG
  4   CONTINUE
      DO 7 I=1,N
C     CANNOT TAKE LOG OF 0
      IF(Q(I).LE.0.0) GO TO 5
C     15 SPACES=1 LOG CYCLE
      IX=IFIX((ALOG10(Q(I))-MIN)*15.+.5)+1
C     PCT IS A SIMPLE ARITHMETIC SCALE
      IY=IFIX((100.-PCT(I))/2.+.5)+1
      IF((IX.LE.76).AND.(IX.GE.1)) GO TO 6
  5   KOUNT=KOUNT+1
      GO TO 7
  6   PLOT(IX,IY)=AST
  7   CONTINUE
C
C     WRITES OUT GRAPH
      DO 8 I=1,51
      IJ=102-2*I
      WRITE (6,11) IJ,(PLOT(J,I),J=1,76)
  8   CONTINUE
C     APPROPRIATE LABELS:
      DO 9 I=1,6
      LABEL(I)=10.**((MIN-1)+I)
  9   CONTINUE
      WRITE (6,12) LABEL
      WRITE (6,13)
      WRITE (6,14) KOUNT
C
C     WRITING A TABLE OF VALUES:
      WRITE (6,15)
      WRITE (6,16) (Q(I),PCT(I),I=1,N)
      RETURN
C
 10   FORMAT ('1',16A4,1X,F7.1,'SQMI',//)
 11   FORMAT (' ',I10,2X,76A1)
 12   FORMAT (' ',T5,6(F10.3,5X))
 13   FORMAT (' ',5X,'PERCENT',/,' ',43X,'Q, IN CFS')
 14   FORMAT ('0','# OF PTS OFF GRAPH=',I3)
 15   FORMAT ('1',6(5X,'Q CFS',7X,'PCT'))
 16   FORMAT (12F10.2)
      END
C     FLODUR IS A SUBROUTINE THAT PRINTS THE FLOW DURATION CURVE FOR
C     NORMALIZED DISCHARGE
      SUBROUTINE FLODUR (Q,PCT,N,HEAD,DRA)
      DIMENSION Q(N), PCT(N), HEAD(16), PLOT(76,51), LABEL(6)
      REAL LABEL
      DATA HORIZO,VERT,BLANK,AST,DOT/'-','|',' ','*','.'
     1/
C
C     KOUNT KEEPS TRACK OF THE # OF PTS OFF THE GRAPH
```

```
      KOUNT=0
      WRITE (6,10) HEAD,DRA
C
C     CREATES BASIC GRAPH OUTLINE:
      DO 1 I=1,76
      DO 1 J=1,51
      PLOT(I,J)=BLANK
    1 CONTINUE
      DO 2 I=2,50
      PLOT(1,I)=VERT
      PLOT(76,I)=VERT
      PLOT(16,I)=DOT
      PLOT(31,I)=DOT
      PLOT(46,I)=DOT
      PLOT(61,I)=DOT
    2 CONTINUE
      DO 3 I=2,75
      PLOT(I,1)=HORIZO
      PLOT(I,51)=HORIZO
      PLOT(I,11)=DOT
      PLOT(I,21)=DOT
      PLOT(I,31)=DOT
      PLOT(I,41)=DOT
    3 CONTINUE
C
C     THIS SECTION ASSIGNS PTS ON GRAPH FOR DISCHARGE,PCT VALUES
      MIN=0
      DO 4 I=1,N
      IEDG=IFIX(ALOG10(Q(I)))-1
      IF(IEDG.LT.MIN) MIN=IEDG
    4 CONTINUE
      DO 7 I=1,N
C     CANNOT TAKE LOG OF 0
      IF(Q(I).LE.0.0) GO TO 5
C     15 SPACES=1 LOG CYCLE
      IX=IFIX((ALOG10(Q(I))-MIN)*15.+.5)+1
C     PCT IS A SIMPLE ARITHMETIC SCALE
      IY=IFIX((100.-PCT(I))/2.+.5)+1
      IF((IX.LE.76).AND.(IX.GE.1)) GO TO 6
    5 KOUNT=KOUNT+1
      GO TO 7
    6 PLOT(IX,IY)=AST
    7 CONTINUE
C
C     WRITES OUT GRAPH
      DO 8 I=1,51
      IJ=102-2*I
      WRITE (6,11) IJ,(PLOT(J,I),J=1,76)
    8 CONTINUE
C     APPROPRIATE LABELS:
      DO 9 I=1,6
      LABEL(I)=10.**((MIN-1)+I)
    9 CONTINUE
      WRITE (6,12) LABEL
      WRITE (6,13)
      WRITE (6,14) KOUNT
C
C     WRITING A TABLE OF VALUES:
      WRITE (6,15)
      WRITE (6,16) (Q(I),PCT(I),I=1,N)
      RETURN
C
   10 FORMAT ('1',16A4,1X,F7.1,'SQMI',//)
   11 FORMAT (' ',I10,2X,76A1)
   12 FORMAT (' ',T5,6(F10.3,5X))
   13 FORMAT (' ',5X,'PERCENT',/,' ',43X,'Q, IN CFS/SQ MI. DRAINAGE AREA
     1')
   14 FORMAT ('0','# OF PTS OFF GRAPH=',I3)
```

```
 15     FORMAT ('1',6(3X,'Q-CFS/SQMI',4X,'PCT'))
 16     FORMAT (12F10.2)
        END
C********** VFLOWDUR ***********************
C       THIS PROGRAM UTILIZES VARIOUS FLOW SEPARATION TECHNIQUES TO
C       DETERMINE THE RELATIVE CONTRIBUTIONS OF GROUND WATER RUNOFF AND
C       SURFACE RUNOFF TO STREAM FLOW
C
        DIMENSION STA(16), DIS(1095), GDIS(1095)
        NOOLD=0
        NCNT=0
C       READS THE STATION NAME AND NUMBER AND THE AREA OF THE BASIN
  1     READ (5,3,END=2)IYR, NO,STA,DRA,N
C
        IF(NO.NE.NOOLD.AND.NCNT.GT.0) CALL PLOTE2
        IF(NO.NE.NOOLD) NCNT=1
        IF(NO.EQ.NOOLD) NCNT=NCNT+1
C
C       READS IN DISCHARGE VALUES FROM CARDS
        READ (5,4,END=2) (DIS(I),I=1,N)
C
C       THE SUBROUTINES ARE EACH SUMMONED BY A DIFFERENT CALL STATEMENT:
C                INSERT AFTER THIS
C       *************************************************************
        CALL VFLWDA (STA,DRA,DIS,N,NCNT)
C       ****************************************************************
C                SUBROUTINES BEFORE THIS
        NOOLD=NO
        GO TO 1
  2     CALL PLOTE2
        STOP
C
C
  3     FORMAT (I2,I8,T1,16A4,2X,F8.0,3X,I3)
  4     FORMAT (10(F8.0))
        END
        SUBROUTINE NDTRI (P,X,D,IE)
C          SEE FORTRAN SSP FOR COMPLETE WRITEUP...
        IE=0
        X=.99999E+74
        D=X
        IF(P) 1,3,2
  1     IE=-1
        GO TO 10
  2     IF(P-1.0) 5,4,1
  3     X=-.99999E+74
  4     D=0.0
        GO TO 10
  5     D=P
        IF(D-0.5) 7,7,6
  6     D=1.0-D
  7     T2=ALOG(1.0/(D*D))
        T=SQRT(T2)
        X=T-(2.515517+0.802853*T+0.010328*T2)/(1.0+1.432788*T+0.189269*T2+
       10.001308*T2)
        IF(P-0.5) 8,8,9
  8     X=-X
  9     D=0.3989423*EXP(-X*X/2.0)
 10     RETURN
        END
        SUBROUTINE VFLWDA (STA,DRA,DIS,N,NCNT)
C          THIS SUBROUTINE CALCULATES A FLOW DURATION CURVE FOR
C          THE YEAR AND PRINTS IT OUT ON THE VERSATEC PLOTTER.
C          ON LOGRITHMIC-PROBABILITY PAPER...
        DIMENSION STA(16), DISDEN(1095), INDX(1095), APER(1095), DIS(1095)
        DIMENSION AY(46), AX(23), DDS(1095)
        DATA AX/.001,.002,.005,.01,.02,.05,.1,.2,.25,.30,.40,.50,.60,.70,.
       175,.80,.90,.95,.98,.99,.995,.998,.999/
```

```
      DATA AY/.001,.002,.003,.004,.005,.006,.007,.008,.009,.01,.02,.03,.
     104,.05,.06,.07,.08,.09,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.,2.,3.,4.,5.,6
     2.,7.,8.,9.,10.,20.,30.,40.,50.,60.,70.,80.,90.,100./
      RNCNT=FLOAT(NCNT)
C        THIS SECTION CREATES THE BASIC GRAPH OUTLINE...
      IF(NCNT.GT.1) GO TO 9
      CALL PLOT (1.0,1.0,-3)
      CALL SYMBOL (0.0,-1.0,0.14,'PERCENT OF TIME DISCHARGE IS EQUALLED
     1OR EXCEEDED',0.0,49)
      CALL SYMBOL (-1.0,1.0,0.14,'DISCHARGE IN CFS/MI 2',90.0,21)
      DO 5 I=1,46
      YPLOT=(ALOG10(AY(I))*2.25)+6.75
      IF(AY(I).LT.0.01) GO TO 1
      IF(AY(I).LT.0.10) GO TO 2
      IF(AY(I).LT.1.00) GO TO 3
      CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,-1)
      GO TO 4
    1 CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,3)
      GO TO 4
    2 CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,2)
      GO TO 4
    3 CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,1)
    4 CALL PLOT (0.3,YPLOT,3)
      CALL PLOT (9.6,YPLOT,2)
    5 CONTINUE
      DO 8 I=1,23
      CALL NDTRI (AX(I),X,D,IER)
      XPLOT=5.0+X*1.5
      IF(AX(I).LT.0.1.OR.AX(I).GT.0.99) GO TO 6
      CALL NUMBER ((XPLOT-0.07),-0.4,0.07,(100.*AX(I)),0.0,-1)
      GO TO 7
    6 CALL NUMBER ((XPLOT-0.07),-0.4,0.07,(100.*AX(I)),0.0,1)
    7 CALL PLOT (XPLOT,0.0,3)
      CALL PLOT (XPLOT,11.3,2)
    8 CONTINUE
    9 NMISS=0
      NOFLOW=0
      MMM=0
      NNM=0
C        DATA SCAN FOR POSSIBLE MISSING DATA OR NO FLOW (<0.01)
      DO 11 I=1,N
      IF(DIS(I).LT.0.0) GO TO 10
      IF(DIS(I).LT.0.01) NOFLOW=NOFLOW+1
      NNM=NNM+1
      DDS(NNM)=DIS(I)
      GO TO 11
   10 NMISS=NMISS+1
   11 CONTINUE
      MMM=MMM+NNM
      M=NNM-1
      DO 13 I=1,M
      L=NNM-1
      DO 12 J=1,L
      IF(DDS(J).LE.DDS(J+1)) GO TO 12
      XR=DDS(J)
      DDS(J)=DDS(J+1)
      DDS(J+1)=XR
   12 CONTINUE
   13 CONTINUE
      DAYS=FLOAT(NNM)
      DO 14 I=1,NNM
      APER(I)=(NNM-I+1.)*100/NNM
      DISDEN(I)=DDS(I)/DRA
   14 CONTINUE
C        WRITES OUT FLOW DURATION TABLE
      WRITE (6,34) STA,DRA
      DO 15 I=1,NNM,8
      IF(NNM.EQ.365.AND.I.EQ.361) GO TO 16
```

```
      II=I+7
      WRITE (6,36) (APER(N),DISDEN(N),N=I,II)
   15 CONTINUE
      GO TO 20
   16 WRITE (6,37) (APER(N),DISDEN(N),N=361,365)
      DELTA1=DISDEN(37)-DISDEN(36)
      DELTA2=DISDEN(329)-DISDEN(328)
      DELTA3=DISDEN(92)-DISDEN(91)
      DELTA4=DISDEN(274)-DISDEN(273)
      Q90=DISDEN(36)+(DELTA1/2)
      Q10=DISDEN(328)+(DELTA2/2)
      Q75=DISDEN(91)+(DELTA3/4)
      Q25=DISDEN(274)-(DELTA4/4)
      IF(Q90.LE.0.) GO TO 17
      IF(Q75.LE.0.) GO TO 18
      GO TO 19
   17 WRITE (6,39)
      IF(Q90.LE.0.) Q90=0.001
      IF(Q75.NE.0.0) GO TO 19
   18 WRITE (6,40)
      IF(Q75.LE.0.) Q75=0.001
      GO TO 19
   19 RT1090=SQRT(Q10/Q90)
      RT2575=SQRT(Q25/Q75)
      WRITE (6,38) RT1090,RT2575
   20 CONTINUE
C     GRAPHS CURVES ON LOG-PROBABILITY SCALE
      INDEX1=NNM/3
      INDEX2=INDEX1*2
      DO 21 I=1,NNM
      DAS=DDS(I)/DRA
      IF(DAS.LT.0.001) DAS=0.001
      YY=(ALOG10(DAS)*2.25)+6.75
      IC=2
      IF(I.EQ.1) IC=3
      XPER=APER(I)/100.
      IF(XPER.GE.1.0) XPER=.999
      IF(XPER.LE.0.001) XPER=.001
      CALL NDTRI (XPER,X,D,IER)
      IF(IER.NE.0) WRITE (6,35)
      XX=5.0+X*1.5
      IF(I.EQ.1) CALL NUMBER ((XX+0.02),YY,0.07,RNCNT,0.0,-1)
      CALL PLOT (XX,YY,IC)
      IF(I.EQ.INDEX1.AND.NCNT.EQ.1) CALL SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(I.EQ.INDEX2.AND.NCNT.EQ.1) CALL SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(I.EQ.INDEX1.AND.NCNT.EQ.2) CALL SYMBOL (XX,YY,0.035,2,0.0,-1)
      IF(I.EQ.INDEX2.AND.NCNT.EQ.2) CALL SYMBOL (XX,YY,0.035,2,0.0,-1)
      IF(I.EQ.INDEX1.AND.NCNT.EQ.3) CALL SYMBOL (XX,YY,0.035,3,0.0,-1)
      IF(I.EQ.INDEX2.AND.NCNT.EQ.3) CALL SYMBOL (XX,YY,0.035,3,0.0,-1)
      IF(XPER.GT.0.95.AND.NCNT.EQ.1.OR.XPER.LT.0.05.AND.NCNT.EQ.1) CALL
     1SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(XPER.GT.0.95.AND.NCNT.EQ.2.OR.XPER.LT.0.05.AND.NCNT.EQ.2) CALL
     1SYMBOL (XX,YY,0.035,2,0.0,-1)
      IF(XPER.GT.0.95.AND.NCNT.EQ.3.OR.XPER.LT.0.05.AND.NCNT.EQ.3) CALL
     1SYMBOL (XX,YY,0.035,3,0.0,-1)
   21 CONTINUE
      IF(NCNT.GT.0) CALL NUMBER ((XX-0.07),YY,0.07,RNCNT,0.0,-1)
      IF(NOFLOW.GT.0) GO TO 22
      GO TO 25
C     INDICATES POSITION OF LAST NO FLOW WITH AN ASTERISK(IF NOFLOW>0)
   22 DO 24 I=1,NNM
      IF(DDS(I).GT.0.01) GO TO 24
      IF(DDS(I).LT.0.01.AND.DDS(I+1).GT.0.01) GO TO 23
      GO TO 24
   23 XPER=APER(I)/100.
      IF(XPER.LE.0.001) XPER=.001
      CALL NDTRI (XPER,X,D,IER)
      XX=5.0+X*1.5
```

```
      CALL SYMBOL (XX,-0.10,0.14,11,0.0,-1)
   24 CONTINUE
C        WRITES SUMMARY INFORMATION AT TOP OF PAGE FOR EACH CURVE
   25 IF(NCNT-2) 26,27,28
   26 CALL NUMBER (0.5,13.25,0.14,RNCNT,0.0,-1)
      CALL SYMBOL (1.0,13.25,0.14,STA,0.0,64)
      XPL=0.0
      GO TO 29
   27 CALL NUMBER (0.5,13.0,0.14,RNCNT,0.0,-1)
      CALL SYMBOL (1.0,13.,0.14,STA,0.0,64)
      XPL=3.3
      GO TO 29
   28 CALL NUMBER (0.5,12.75,0.14,RNCNT,0.0,-1)
      CALL SYMBOL (1.0,12.75,0.14,STA,0.0,64)
      XPL=6.6
   29 CALL NUMBER ((XPL+0.5),12.5,0.14,RNCNT,0.0,-1)
      CALL NUMBER (XPL,12.25,0.07,DAYS,0.0,-1)
      CALL SYMBOL ((XPL+0.28),12.25,0.07,'DAYS PLOTTED',0.0,12)
      IF(NMISS.GT.0) GO TO 30
      IF(NOFLOW.GT.0) GO TO 31
      GO TO 32
   30 RMISS=FLOAT(NMISS)
      CALL NUMBER (XPL,12.0,0.07,RMISS,0.0,-1)
      CALL SYMBOL ((XPL+0.28),12.0,0.07,' DAYS MISSING DATA',0.0,18)
      IF(NOFLOW.EQ.0) GO TO 32
   31 ROFLOW=FLOAT(NOFLOW)
      CALL NUMBER (XPL,11.75,0.07,ROFLOW,0.0,-1)
      CALL SYMBOL ((XPL+0.28),11.75,0.07,' DAYS NO FLOW(*)',0.0,16)
   32 IF(NNM.NE.365) GO TO 33
      CALL SYMBOL (XPL,11.5,0.07,'(Q 10 /Q 90 ) 1/2 =',0.0,19)
      CALL NUMBER ((XPL+1.75),11.5,0.07,RT1090,0.0,2)
      CALL SYMBOL (XPL,11.30,0.07,'(Q 25 /Q 75 ) 1/2 =',0.0,19)
      CALL NUMBER ((XPL+1.75),11.30,0.07,RT2575,0.0,2)
   33 RETURN
C
   34 FORMAT ('1','FLOW-DURATION CURVE FOR',17X,16A4,2X,F8.2,2X,'SQ.MI')
   35 FORMAT ('0',' * * * * * * * * * * W A R N I N G  ERROR IN NDTRI')
   36 FORMAT (' ',4X,8(F6.2,1X,F6.3,3X))
   37 FORMAT (' ',4X,5(F6.2,1X,F6.3,3X))
   38 FORMAT ('0',7X,'THE RATIO (Q10/Q90)**1/2 =',F8.2,10X,'(Q25/Q75)**1
     1/2 =',F8.2)
   39 FORMAT (' ',' Q90 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANINGL
     1ESS.')
   40 FORMAT (' ','  Q75 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANIN
     1GLESS.')
      END
C********** FLOW *************************
C   HYDROGRAPH FLOW SEPARATION PROGRAM
C
C        MODIFED BY R. DIXON FROM PROGRAMS WRITTEN BY R.J. HENNING
C         AND T. CROLL    ( 77.09.22 )
C        PROBLEMS WITH THIS PROGRAM SHOULD BE DIRECTED TO:
C                 ROGER J. HENNING
C             C/O DR. WAYNE A. PETTYJOHN
C                 DEPARTMENT OF GEOLOGY AND MINERALOGY
C                 125 S. OVAL MALL
C                 THE OHIO STATE UNIVERSITY
C                 COLUMBUS, OHIO   43210
C
C     ***************************************************************
C             OSU IRCC FORTRAN (G1) COMPILER
C                  SUBROUTINE REREAD IS COMPILED IN IBM 370/VM
C                    ASSEMBLER LANGUAGE .  THIS PROGRAM CAN BE
C                    SUPPLIED IN A VERSION THAT DOES NOT REQUIRE
C                    REREAD CAPABILITIES.  FORTRAN 'REWIND' CAN BE
C                    SUBSTITUTED, BUT IS IS NOT COST EFFICIENT.
C
C        INPUT TO THIS PROGRAM CONSISTS OF CONTROL CARDS WRITTEN
```

```
C        IN A "COMMAND LANGUAGE" AND DISCHARGE AND STATION DATA.
C
C        THIS PROGRAM IS DESIGNED TO READ IN DISCHARGE DATA FROM CARDS
C        AND DO VARIOUS CALCULATIONS WITH A VARIETY OF OUTPUT MODES.
C        THE COMMAND LANGUAGE CONSISTS OF ENGLISH LANUAGE COMMANDS
C        THAT DETERMINE THE OPTIONS TO BE USED AND CAUSES THE
C        APPROPRIATE BRANCHING.
C        THE IMPORTANT SECTION OF THE CONTROL "COMMAND LANGUAGE CARDS"
C        IS CARD COLUMNS 22 THROUGH 26.  IF THE CONTROL CARDS DO NOT
C        CONTAIN THE EXPECTED LETTER-NUMBER COMBINATIONS IN THESE
C        COLUMNS, THE PROGRAM WILL FLUSH TO THE NEXT READ COMMAND.
C        THE CONTROL CARD OPTIONS AND THE FUNCTION THEY PERFORM ARE:
C
C     CC  123456789..............................
C     ----------------------------------------------------------------
C     /
C     I
C     I      INPUT COMMAND CARD
C     I
C     IREAD DISCHARGE DATA FROM CARDS(10 TO A CARD,8 COLUMNS EACH.)
C     I
C     I
C     I      CALCULATION COMMAND CARDS
C     I
C     IAND CALCULATE BY THE FIXED INTERVAL METHOD
C     IAND CALCULATE BY THE SLIDING INTERVAL METHOD
C     IAND CALCULATE BY THE LOCAL MINIMA METHOD
C     I
C     I      OUTPUT COMMAND CARDS
C     I
C     IAND PRINT OUT SUMMARY STATISTICS FOR THE YEAR
C     IAND PRINT OUT MONTH-BY-MONTH STATISTICS
C     IAND PRINT OUT A HYDROGRAPH ON THE LINE PRINTER
C     IAND PUNCH CARDS TO BE USED AS INPUT TO THE CALCOMP PLOT PROGRAM
C     IAND ON VERSATEC PLOT A HYDROGRAPH WITH SEPARATION
C     IAND PRINT OUT A FLOW DURATION CURVE ON THE LINE PRINTER
C     IAND ON THE VERSATEC PLOT A FLOW DURATION CURVE
C     I
C     I      SAMPLE DATA CARDS
C     I
C     I      TITLE CARD (YR. IN CC 1-2,STA. NO. IN CC 3-10, LITERAL
C     I        TITLE IN CC 11-66, DRAINAGE AREA IN CC 67-74 (WITH
C     I        DECIMAL POINT), AND 365 IN CC 78-80)
C     I
C     I6303123456 OHIO STREAM AT AMERICUS, OH.              123.4    36
C     I
C     I      DISCHARGE DATA CARDS (37 CARDS PER STATION PER YEAR,
C     I        WITH 10 DAYS PER CARD, EACH PUNCHED IN A 8 COLUMN FIELD,
C     I        EITHER WITH A DECIMAL POINT OR RIGHT JUSTIFIED.)
C     I
C     I      1.2     1.9     9.5     235     2580    5678    785.    ...
C     I
C
C     $$**** THE PROPER SEQUENCE OF CARDS SHOULD BE:
C
C     A  *JCL PROGRAM CONTROL CARDS (DEPENDING ON THE COMPUTER INSTALLAT
C     B  *INPUT COMMAND CARD
C     C  *STATION TILE CARD
C     D  *37 DISCHARGE DATA CARDS
C     E  *CALCULATION COMMAND CARD (ONE ONLY, FOLLOWED BY FROM ONE TO
C          SEVEN OUTPUT COMMAND CARDS.)
C     F  *OUTPUT COMMAND CARD(S)  (AT LEAST ONE)
C
C        REPEAT E AND F FOR AS MANY DIFFERENT CALCULATION TECHNIQUES
C          AS DESIRED.
C     ** SPECIAL NOTE *** FLOW DURATION OUTPUT COMMAND CARD(S) MUST
C          ALWAYS BE THE LAST ROUTINES CALLED FOR ANY STATION (IF
C          DESIRED FOR THAT STATION.)
```

```
C
C         SEQUENCE OF B THROUGH F CAN BE REPEATED FOR AS MANY
C         STATIONS AS DESIRED.
C
C     *****************************************************************
      DIMENSION DIS(365)
      LOGICAL FLUSH/.FALSE./
      INTEGER*4 CDTYPE(11),TYPE,CARD(20),READ/'READ'/
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA CDTYPE/'ROM ','FIXE','SLID','LOCA','MMAR','Y-MO','GRAP','A HY
     1','A FL','DURA',' USE'/
      NN=0
C     CARD-TYPE SYSTEM TO RECOGNIZE INPUT CARDS AND BRANCH ACCORDINGLY.
      CALL REREAD
 1    CONTINUE
      READ (5,21,END=19) CARD
      WRITE (6,22) CARD
      READ (99,23) TYPE
      DO 2 I=1,11
      IF(CDTYPE(I).EQ.TYPE) GO TO 3
 2    CONTINUE
      WRITE (6,24)
      FLUSH=.TRUE.
      GO TO 1
 3    CONTINUE
      IF((FLUSH).AND.(CARD(1).NE.READ)) GO TO 1
      GO TO (4,5,6,7,8,9,10,11,12,13,14), I
C
 4    CONTINUE
C     READ DISCHARGE DATA FROM CARDS(10 TO A CARD, 8 COLUMNS EACH.)
      FLUSH=.FALSE.
      CALL NORERD
      GO TO 15
C
 5    CONTINUE
C     AND CALCULATE BY THE FIXED INTERVAL METHOD.
      CALL FXINTR
      GO TO 1
C
 6    CONTINUE
C     AND CALCULATE BY THE SLIDING INTERVAL METHOD
      CALL SLINTR
      GO TO 1
C
 7    CONTINUE
C     AND CALCULATE BY THE LOCAL MINIMA METHOD
      CALL LOCMIN
      GO TO 1
C
 8    CONTINUE
C     AND PRINT OUT SOME SUMMARY STATISTICS FOR THE YEAR
      CALL STATGW
      GO TO 1
C
 9    CONTINUE
C     AND PRINT OUT MONTH-BY-MONTH SUMMARY STATISTICS
      CALL MONTHS
      GO TO 1
C
 10   CONTINUE
C     AND PRINT OUT A HYDROGRAPH ON THE LINE PRINTER
      CALL HYDGRH
      GO TO 1
C
 11   CONTINUE
C     AND ON VERSATEC PLOT A HYDROGRAPH WITH SEPARATION
      CALL VERSAP
      GO TO 1
```

```
C
 12    CONTINUE
C      AND ON VERSATEC PLOT A FLOW DURATION CURVE
       CALL VFLWDA
       GO TO 1
C
 13    CONTINUE
C      AND PRINT OUT A FLOW DURATION CURVE ON THE LINE PRINTER
       CALL FLWDUR
       GO TO 1
C
 14    CONTINUE
C      AND PUNCH CARDS TO BE USED AS INPUT TO THE CALCOMP PLOT PROGRAM
       CALL PUNCHR
       GO TO 1
C
C
 15    READ (5,25) STA,DRA,N
       WRITE (6,29)
       WRITE (6,30) STA,DRA,N
       WRITE (6,29)
       READ (5,26) DIS
       IF(N.NE.365) GO TO 17
       NN=NN+1
       DMAX=0.0
       NMISS=0
       DO 16 I=1,365
       IF(DMAX.LT.DIS(I)) DMAX=DIS(I)
       IF(DIS(I).LT.0.0) NMISS=NMISS+1
       DSS(I)=DIS(I)
       IF(DIS(I).LT.0.0) DSS(I)=DSS(I-1)
 16    CONTINUE
       IF(NMISS.GT.0) WRITE (6,31) NMISS
       IF(DMAX/DRA.GT.100.0) GO TO 18
       RINTR=DRA**0.2
       RINTR=RINTR*2.
       IF(RINTR.LE.4.0) INTRVL=3
       IF(RINTR.LE.6.0.AND.RINTR.GT.4.0) INTRVL=5
       IF(RINTR.LE.8.0.AND.RINTR.GT.6.0) INTRVL=7
       IF(RINTR.LE.10.0.AND.RINTR.GT.8.0) INTRVL=9
       IF(RINTR.GT.10.0) INTRVL=11
       CALL REREAD
       GO TO 1
C      *****************************************************************
 17    WRITE (6,27) N
       GO TO 20
 18    WRITE (6,28) DMAX,DRA
       GO TO 20
C
 19    STOP
C
 20    CONTINUE
C      FLUSH TO NEXT 'READ' CARD.
       FLUSH=.TRUE.
       CALL REREAD
       GO TO 1
C
C
C
 21    FORMAT (20A4)
 22    FORMAT (//,1X,20A4)
 23    FORMAT (T22,A4)
 24    FORMAT (' THE INPUT CARD PRINTED ABOVE IS NOT ONE OF THE',' ALLOWA
      1BLE STATEMENTS.'/,' THIS BASIN IS THEREFORE ABORTED.')
 25    FORMAT (T1,16A4,2X,F8.0,3X,I3)
 26    FORMAT (36(10(F8.0)/),5(F8.0))
 27    FORMAT ('0','***** ERROR *****  N IS ',I3,'.  THIS PROGRAM IS DESI
      1GNED FOR WATER YEARS OF 365 DAYS'/'0',' BEGINNING IN OCTOBER.  PLE
```

```
     2ASE USE ANOTHER PROGRAM FOR OTHER TYPES OF RECORDS.')
28    FORMAT ('0','***** ERROR *****  MAXIMUM DISCHARGE IS ',F10.0,'. DR
     1AINAGE AREA IS ',F8.2,'.  '/'0','            THE RATIO DISCHARGE/DR
     2AINAGE AREA EXCEEDS 100 CFS/SQ.MI.')
29    FORMAT ('0',' ******************************************************'
     1)
30    FORMAT ('0',2X,16A4,2X,F8.2,2X,I3)
31    FORMAT ('0',' ***** NOTE ***** THERE ARE ',I3,' DAYS THAT HAVE MIS
     1SING DATA.  VALUES FOR THESE DAYS HAVE BEEN'/'0',' SET TO THE LAST
     2 VALID DATA VALUES.  INSPECT OUTPUT CAREFULLY.')
      END
      SUBROUTINE FXINTR
      DIMENSION SECH(6)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA SECH(2),SECH(3),SECH(4),SECH(5),SECH(6)/'DAY ','FIXE','D IN',
     1'TERV','AL  '/
      DATA THREE,FIVE,SEVEN,NINE,ELEVEN/' 3  ',' 5  ',' 7  ',' 9  ',' 11
     1 '/
      DO 1 J=2,6
1     TECH(J)=SECH(J)
      IF(INTRVL.EQ.3) TECH(1)=THREE
      IF(INTRVL.EQ.5) TECH(1)=FIVE
      IF(INTRVL.EQ.7) TECH(1)=SEVEN
      IF(INTRVL.EQ.9) TECH(1)=NINE
      IF(INTRVL.EQ.11) TECH(1)=ELEVEN
      WRITE (6,8) INTRVL
      K=365/INTRVL
      DO 4 I=1,K
      PMIN=100000.
      L1=((I-1)*INTRVL)+1
      L2=I*INTRVL
      DO 2 J=L1,L2
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
2     CONTINUE
      DO 3 J=L1,L2
      GDIS(J)=PMIN
3     CONTINUE
4     CONTINUE
      M1=(K*INTRVL)+1
      IF(K*INTRVL.EQ.365) GO TO 7
      PMIN=100000.
      DO 5 J=M1,365
      IF(DSS(J).LT.0.0) GO TO 5
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
5     CONTINUE
      DO 6 J=M1,365
      IF(DSS(J).LT.0.0) GO TO 6
      GDIS(J)=PMIN
6     CONTINUE
7     RETURN
C
C
C
8     FORMAT ('0','FIXED INTERVAL, INTERVAL=',I3,' DAYS')
      END
      SUBROUTINE SLINTR
      DIMENSION SECH(6)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA SECH(2),SECH(3),SECH(4),SECH(5),SECH(6)/'DAY ','SLID','ING ',
     1'INTE','RVAL'/
      DATA THREE,FIVE,SEVEN,NINE,ELEVEN/' 3  ',' 5  ',' 7  ',' 9  ',' 11
     1 '/
      DO 1 J=2,6
1     TECH(J)=SECH(J)
      INT=INTRVL
      IF(INT.EQ.3) TECH(1)=THREE
      IF(INT.EQ.5) TECH(1)=FIVE
      IF(INT.EQ.7) TECH(1)=SEVEN
```

```
      IF(INT.EQ.9) TECH(1)=NINE
      IF(INT.EQ.11) TECH(1)=ELEVEN
      WRITE (6,10) INTRVL
      INT=(INTRVL-1)/2
      DO 9 I=1,365
      IF(DSS(I).LT.0.0) GO TO 9
      IF(I-(INT+1)) 5,2,2
    2 IF((365-I)-(INT+1)) 7,3,3
    3 PMIN=100000.
      K1=I-INT
      K2=I+INT
      DO 4 J=K1,K2
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
    4 CONTINUE
      GDIS(I)=PMIN
      GO TO 9
    5 PMIN=100000.
      K2=I+INT
      DO 6 J=1,K2
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
    6 CONTINUE
      GDIS(I)=PMIN
      GO TO 9
    7 PMIN=100000.
      K1=I-INT
      DO 8 J=K1,365
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
    8 CONTINUE
      GDIS(I)=PMIN
    9 CONTINUE
      RETURN
C
C
C
   10 FORMAT ('0','SLIDING INTERVAL,INTERVAL=',I3,' DAYS')
      END
      SUBROUTINE LOCMIN
      DIMENSION IPOINT(400), SECH(6)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA SECH(2),SECH(3),SECH(4),SECH(5),SECH(6)/'DAY ','LOCA','L MI',
     1'NIMA','    '/
      DATA THREE,FIVE,SEVEN,NINE,ELEVEN/' 3  ',' 5  ',' 7  ',' 9  ',' 11
     1 '/
      DO 1 J=2,6
    1 TECH(J)=SECH(J)
      INT=INTRVL
      IF(INT.EQ.3) TECH(1)=THREE
      IF(INT.EQ.5) TECH(1)=FIVE
      IF(INT.EQ.7) TECH(1)=SEVEN
      IF(INT.EQ.9) TECH(1)=NINE
      IF(INT.EQ.11) TECH(1)=ELEVEN
      WRITE (6,24) INTRVL
      NUMPT=0
      IF(INTRVL.EQ.3) GO TO 2
      IF(INTRVL.EQ.5) GO TO 5
      IF(INTRVL.EQ.7) GO TO 8
      IF(INTRVL.EQ.9) GO TO 11
      IF(INTRVL.GE.11) GO TO 14
    2 L=365-1
      DO 4 I=2,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I-1)) GO TO 3
      GO TO 4
    3 NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
    4 CONTINUE
      GO TO 17
    5 L=365-2
      DO 7 I=3,L
```

```
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I-1).AND.DSS(I).LE.DSS(I+2
     1).AND.DSS(I).LE.DSS(I-2)) GO TO 6
      GO TO 7
6     NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
7     CONTINUE
      GO TO 17
8     L=365-3
      DO 10 I=4,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I+2).AND.DSS(I).LE.DSS(I+3
     1).AND.DSS(I).LE.DSS(I-1).AND.DSS(I).LE.DSS(I-2).AND.DSS(I).LE.DSS(
     2I-3)) GO TO 9
      GO TO 10
9     NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
10    CONTINUE
      GO TO 17
11    L=365-4
      DO 13 I=5,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I+2).AND.DSS(I).LE.DSS(I+3
     1).AND.DSS(I).LE.DSS(I-1).AND.DSS(I).LE.DSS(I-2).AND.DSS(I).LE.DSS(
     2I-3).AND.DSS(I).LE.DSS(I-4).AND.DSS(I).LE.DSS(I+4)) GO TO 12
      GO TO 13
12    NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
13    CONTINUE
      GO TO 17
14    L=365-5
      DO 16 I=6,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I+2).AND.DSS(I).LE.DSS(I+3
     1).AND.DSS(I).LE.DSS(I-1).AND.DSS(I).LE.DSS(I-2).AND.DSS(I).LE.DSS(
     2I-3).AND.DSS(I).LE.DSS(I-4).AND.DSS(I).LE.DSS(I+4).AND.DSS(I).LE.D
     3SS(I-5).AND.DSS(I).LE.DSS(I+5)) GO TO 15
      GO TO 16
15    NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
16    CONTINUE
17    K=NUMPT-1
      J=IPOINT(1)
      L=IPOINT(NUMPT)
      DO 18 IJ=1,J
      GDIS(IJ)=DSS(J)
18    CONTINUE
      DO 19 IJ=L,365
      GDIS(IJ)=DSS(L)
19    CONTINUE
      DO 21 I=1,K
      IP1=IPOINT(I)
      IP2=IPOINT(I+1)
      GDIS(IP1)=DSS(IP1)
      GDIS(IP2)=DSS(IP2)
      ISTART=IP1
      IEND=IP2
      DO 20 J=ISTART,IEND
      X=J-IP1
      Y=IP2-IP1
      IF(GDIS(IP1).EQ.0.0) GDIS(IP1)=0.01
      IF(GDIS(IP2).EQ.0.0) GDIS(IP2)=0.01
      GDIS(J)=10.**((X/Y)*(ALOG10(GDIS(IP2))-ALOG10(GDIS(IP1)))+ALOG10(G
     1DIS(IP1)))
20    CONTINUE
21    CONTINUE
      DO 22 IJK=1,365
      IF(GDIS(IJK).GT.DSS(IJK)) GDIS(IJK)=DSS(IJK)
22    CONTINUE
      RETURN
C
C
```

```
C
 24   FORMAT ('0','LOCAL MINIMA. INTERVAL=',I3,' DAYS')
      END
      SUBROUTINE STATGW
C      * * THIS SUBROUTINE CALCULATES AND PRINTS OUT SUMMARY
C         INFORMATION ABOUT THE SEPARATION.  IT IS ONLY TO BE USED
C         AFTER ONE OF THE SEPARATION TECHNIQUES HAS BEEN CALLED.
      REAL MDSS,LMIN,LMAX
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DAYS=0.0
      LMIN=100000.
      LMAX=.0
      TOTDIS=.0
      TOTGW=0.0
      DO 1 I=1,365
      IF(DSS(I).LT.0.0) GO TO 1
      DAYS=DAYS+1
      TOTDIS=TOTDIS+DSS(I)
      TOTGW=TOTGW+GDIS(I)
      IF(DSS(I).LT.LMIN) LMIN=DSS(I)
      IF(DSS(I).GT.LMAX) LMAX=DSS(I)
  1   CONTINUE
      TOQUAN=86400.*TOTDIS
      TOQUGW=86400.*TOTGW
      TOTGWI=0.03719*(TOTGW/DRA)
      TOTQIN=0.03719*(TOTDIS/DRA)
      MDSS=TOTDIS/DAYS
      WRITE (6,2)
      WRITE (6,3) TOQUAN,TOTQIN
      WRITE (6,4) LMIN
      WRITE (6,5) MDSS
      WRITE (6,6) LMAX
      TDSSMI=TOQUAN/DRA
      TDGWSM=TOQUGW/DRA
      WRITE (6,7) TDSSMI
      WRITE (6,8) TOQUGW,TOTGWI
      WRITE (6,9) TDGWSM
      PERCEN=(TOQUGW/TOQUAN)*100.
      WRITE (6,10) PERCEN
      RECH=TDGWSM*7.48/DAYS
      IRECH=IFIX(RECH/1000.)
      RECHG=FLOAT(IRECH*1000)
      IF(RECH.LE.10000) RECHG=RECH
      WRITE (6,11) RECHG
      WRITE (6,12)
      RETURN
C
C
C
  2   FORMAT ('0')
  3   FORMAT ('0','TOTAL DISCHARGE FOR THE WATER YEAR',11X,1PE10.3,1X,'C
     1F',20X,'OR  ',0PF7.2,'  INCHES')
  4   FORMAT ('0','MINIMUM DISCHARGE',30X,F8.2,1X,'CFS')
  5   FORMAT ('0','MEAN DISCHARGE',33X,F8.2,1X,'CFS')
  6   FORMAT ('0','MAXIMUM DISCHARGE',30X,F8.2,1X,'CFS')
  7   FORMAT ('0','TOTAL DISCHARGE/YR/BASIN AREA',16X,1PE10.3,1X,'CF/SQ.
     1MI')
  8   FORMAT ('0','THE TOTAL GROUND WATER DISCHARGE FOR A YEAR',2X,1PE10
     1.3,1X,'CF',20X,'OR  ',0PF7.2,'  INCHES')
  9   FORMAT ('0','TOTAL GROUND WATER DISCHARGE/YR/BASIN AREA',3X,1PE10.
     13,1X,'CF /SQ.MI.')
 10   FORMAT ('0','% OF TOTAL DISCHARGE DUE TO GROUND WATER RUNOFF',F7.2
     1)
 11   FORMAT ('0',60X,'THE RECHARGE RATE  = ',F10.0,'   GPD/SQ.MI.')
 12   FORMAT ('0','* * * * * * * * * * * * * * * * * * * * '/)
      END
      SUBROUTINE MONTHS
C      * * THIS SUBROUTINE CALCULATES INFORMATION ABOUT THE
```

```
C         SEPARATION ON A MONTHLY BASIS.  IT IS TO BE USED ONLY
C         AFTER A SEPARATION SUBROUTINE HAS BEEN CALLED.
      DIMENSION MONTH(12,6)
      REAL MONTH
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      TOTALQ=0.000000000000001
      TOTLGW=0.0
      DO 2 I=1,12
      DO 1 J=1,6
      MONTH(I,J)=0.0
 1    CONTINUE
 2    CONTINUE
      DO 3 I=1,31
      IF(DSS(I).LT.0.0) GO TO 3
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
 3    CONTINUE
      MONTH(1,1)=TOTALQ*86400.
      MONTH(1,2)=0.03719*(TOTALQ/DRA)
      MONTH(1,3)=TOTLGW*86400.
      MONTH(1,4)=0.03719*(TOTLGW/DRA)
      MONTH(1,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(1,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(1,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 4 I=32,61
      IF(DSS(I).LT.0 0) GO TO 4
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
 4    CONTINUE
      MONTH(2,1)=TOTALQ*86400.
      MONTH(2,2)=0.03719*(TOTALQ/DRA)
      MONTH(2,3)=TOTLGW*86400.
      MONTH(2,4)=0.03719*(TOTLGW/DRA)
      MONTH(2,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/30.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(2,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(2,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 5 I=62,92
      IF(DSS(I).LT.0.0) GO TO 5
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
 5    CONTINUE
      MONTH(3,1)=TOTALQ*86400.
      MONTH(3,2)=0.03719*(TOTALQ/DRA)
      MONTH(3,4)=0.03719*(TOTLGW/DRA)
      MONTH(3,3)=TOTLGW*86400.
      MONTH(3,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(3,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(3,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 6 I=93,123
      IF(DSS(I).LT.0.0) GO TO 6
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
 6    CONTINUE
      MONTH(4,1)=TOTALQ*86400.
      MONTH(4,3)=TOTLGW*86400.
      MONTH(4,2)=0.03719*(TOTALQ/DRA)
```

```
      MONTH(4,4)=0.03719*(TOTLGW/DRA)
      MONTH(4,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(4,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(4,6)=RECH
      TOTALQ=0.0000000001
      TOTLGW=0.0
      DO 7 I=124,151
      IF(DSS(I).LT.0.0) GO TO 7
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
7     CONTINUE
      MONTH(5,1)=TOTALQ*86400.
      MONTH(5,2)=0.03719*(TOTALQ/DRA)
      MONTH(5,3)=TOTLGW*86400.
      MONTH(5,4)=0.03719*(TOTLGW/DRA)
      MONTH(5,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/28.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(5,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(5,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 8 I=152,182
      IF(DSS(I).LT.0.0) GO TO 8
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
8     CONTINUE
      MONTH(6,1)=TOTALQ*86400.
      MONTH(6,2)=0.03719*(TOTALQ/DRA)
      MONTH(6,3)=TOTLGW*86400.
      MONTH(6,4)=0.03719*(TOTLGW/DRA)
      MONTH(6,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(6,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(6,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 9 I=183,212
      IF(DSS(I).LT.0.0) GO TO 9
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
9     CONTINUE
      MONTH(7,1)=TOTALQ*86400.
      MONTH(7,2)=0.03719*(TOTALQ/DRA)
      MONTH(7,3)=TOTLGW*86400.
      MONTH(7,4)=0.03719*(TOTLGW/DRA)
      MONTH(7,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/30.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(7,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(7,6)=RECH
      TOTALQ=0.0000000001
      TOTLGW=0.0
      DO 10 I=213,243
      IF(DSS(I).LT.0.0) GO TO 10
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
10    CONTINUE
      MONTH(8,1)=TOTALQ*86400.
      MONTH(8,2)=0.03719*(TOTALQ/DRA)
      MONTH(8,3)=TOTLGW*86400.
      MONTH(8,5)=(TOTLGW/TOTALQ)*100.
      MONTH(8,4)=0.03719*(TOTLGW/DRA)
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
```

```
      MONTH(8,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(8,6)=RECH
      TOTLGW=0.0
      TOTALQ=0.000000000001
      DO 11 I=244,273
      IF(DSS(I).LT.0.0) GO TO 11
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
11    CONTINUE
      MONTH(9,1)=TOTALQ*86400.
      MONTH(9,2)=0.03719*(TOTALQ/DRA)
      MONTH(9,3)=TOTLGW*86400.
      MONTH(9,4)=0.03719*(TOTLGW/DRA)
      MONTH(9,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/30.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(9,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(9,6)=RECH
      TOTALQ=0.00000000001
      TOTLGW=0.0
      DO 12 I=274,304
      IF(DSS(I).LT.0.0) GO TO 12
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
12    CONTINUE
      MONTH(10,1)=TOTALQ*86400.
      MONTH(10,2)=0.03719*(TOTALQ/DRA)
      MONTH(10,3)=TOTLGW*86400.
      MONTH(10,4)=0.03719*(TOTLGW/DRA)
      MONTH(10,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(10,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(10,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 13 I=305,335
      IF(DSS(I).LT.0.0) GO TO 13
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
13    CONTINUE
      MONTH(11,1)=TOTALQ*86400.
      MONTH(11,2)=0.03719*(TOTALQ/DRA)
      MONTH(11,3)=TOTLGW*86400.
      MONTH(11,4)=0.03719*(TOTLGW/DRA)
      MONTH(11,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(11,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(11,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 14 I=336,365
      IF(DSS(I).LT.0.0) GO TO 14
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
14    CONTINUE
      MONTH(12,1)=TOTALQ*86400.
      MONTH(12,2)=0.03719*(TOTALQ/DRA)
      MONTH(12,3)=TOTLGW*86400.
      MONTH(12,4)=0.03719*(TOTLGW/DRA)
      MONTH(12,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/30.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(12,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(12,6)=RECH
      WRITE (6,15)
      WRITE (6,16) (MONTH(I,1),I=1,12)
```

```
      WRITE (6,17) (MONTH(I,2),I=1,12)
      WRITE (6,18) (MONTH(I,3),I=1,12)
      WRITE (6,19) (MONTH(I,4),I=1,12)
      WRITE (6,20) (MONTH(I,5),I=1,12)
      WRITE (6,21) (MONTH(I,6),I=1,12)
      WRITE (6,22)
      RETURN
C
C
C
 15   FORMAT ('0',15X,'OCT',7X,'NOV',7X,'DEC',7X,'JAN',7X,'FEB',7X,'MAR'
     1,7X,'APR',7X,'MAY',7X,'JUN',7X,'JUL',7X,'AUG',7X,'SEP')
 16   FORMAT ('0','TOTAL Q(CF) ',12(1PE10.2))
 17   FORMAT ('0','TOTAL Q(IN) ',12(F10.3))
 18   FORMAT ('0','GW (CF )    ',12(1PE10.2))
 19   FORMAT ('0','GW (IN )    ',12(F10.3))
 20   FORMAT ('0','% AS G W    ',12(F10.2))
 21   FORMAT ('0','RR GPD/MI2  ',12(F10.0))
 22   FORMAT ('0','* * * * * * * * * * * * * * * * * * * * * * * * * *'/
     1)
      END
      SUBROUTINE VERSAP
C     *  THIS SUBROUTINE PRODUCES OUTPUT ON THE VERSATEC PLOTTER ****
      DIMENSION BCD(3)
      DIMENSION TOTAL(4), GROUND(6), GROUNP(5), RECHAR(4), CF(5), GPD(3)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA BCD/'LOG ','M 3 ','/S  '/
      DATA TOTAL/'TOTA','L DI','SCHA','RGE '/
      DATA GROUND/'GROU','ND W','ATER',' RUN','OFF ','    '/
      DATA GROUNP/'GROU','ND W','ATER',' AS ','%   '/
      DATA RECHAR/'RECH','ARGE',' RAT','E   '/
      DATA CF/'CF O','R   ','    ','  IN','CHES'/
      DATA GPD/'GPD ','/SQ.',' MI.'/
C     ** CALCULATE SUMMARY INFORMATION                       **********
      DIMENSION TITLE(16)
      DAYS=0.0
      TOTDIS=.0
      RMAX=0.0
      RMIN=100000000.
      TOTGW=0.0
      DO 1 I=1,365
      DAYS=DAYS+1.0
      IF(DSS(I).GT.RMAX) RMAX=DSS(I)
      IF(DSS(I).LT.RMIN) RMIN=DSS(I)
      TOTDIS=TOTDIS+DSS(I)
      TOTGW=TOTGW+GDIS(I)
 1    CONTINUE
      TOQUAN=86400.*TOTDIS
      TOQUGW=86400.*TOTGW
      TOTGWI=0.03719*(TOTGW/DRA)
      TOTQIN=0.03719*(TOTDIS/DRA)
      TDSSMI=TOQUAN/DRA
      TDGWSM=TOQUGW/DRA
      PERCEN=(TOQUGW/TOQUAN)*100.
      RECH=TDGWSM*7.48/DAYS
      IRECH=IFIX(RECH/1000.)
      RECHG=FLOAT(IRECH*1000)
      IF(RECH.LE.10000) RECHG=RECH
      XQUAN=ALOG10(TOQUAN)
      YQUAN=IFIX(XQUAN)
      TOQUAN=10**(XQUAN-YQUAN)
      TOTQE=YQUAN
      XQUGW=ALOG10(TOQUGW)
      YQUGW=IFIX(XQUGW)
      TOQUGW=10**(XQUGW-YQUGW)
      TOQGWE=YQUGW
      DO 2 J=1,16
 2    TITLE(J)=STA(J)
```

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C       ** PLOTTING OF HYDROGRAPH  (USING OSU GPP EMULATOR) ***********
        CALL AXSN (1.0,1.0,'DAYS',-4,9.125,0.,0.,40.,0.75,2,-1)
        CALL AXSN (1.,1.,'LOG DISCHARGE,CFS',17,5.,90.,-2.,1.6,0.625,0,1)
        CALL PLOT (1.0,1.0,3)
        DO 3 I=1,365
        IC=2
        IF(I.EQ.1) IC=3
        X=1.025+I*(.025)
        IF(DSS(I).EQ.0.0) DSS(I)=0.01
        IF(DSS(I).LT.0.01) IC=3
        Y=2.25+(ALOG10(DSS(I))/1.6)
        CALL PLOT (X,Y,IC)
 3      CONTINUE
        CALL PLOT (0.0,0.0,3)
        DO 4 I=1,365
        IC=2
        IF(I.EQ.1) IC=3
        X=1.025+I*(.025)
        IF(GDIS(I).EQ.0.0) GDIS(I)=0.01
        IF(GDIS(I).LT.0.01) IC=3
        Y=2.25+(ALOG10(GDIS(I))/1.6)
        CALL PLOT (X,Y,IC)
 4      CONTINUE
        CALL AXSN (10.150,1.,'DISCHARGE',-0,-5.,90.,-2.,1.6,0.625,0,1)
        CALL AXSN (10.3,1.343,BCD,-12,5.,90.,-3.,1.6,0.625,0,1)
        CALL AXSN (10.000,6.000,'DAYS',0,-9.125,180.,0.,40.,0.75,2,-1)
        IF(RMIN.GT.1.0) GO TO 5
        IF(RMAX.LT.10000) GO TO 6
        IF(RMAX.LT.100000.AND.RMIN.GT.0.1) GO TO 7
        GO TO 8
 5      CALL SYMBOL (2.0,1.25,0.14,RECHAR,0.0,16)
        CALL NUMBER (4.5,1.25,0.14,RECHG,0.0,-1)
        CALL SYMBOL (6.5,1.25,0.14,GPD,0.0,12)
        CALL SYMBOL (2.0,1.50,0.14,GROUNP,0.0,20)
        CALL NUMBER (5.1,1.50,0.14,PERCEN,0.0,1)
        CALL SYMBOL (2.0,1.75,0.14,GROUND,0.0,24)
        CALL NUMBER (5.1,1.75,0.14,TOQUGW,0.0,3)
        CALL SYMBOL (5.85,1.75,0.14,69,0.0,-1)
        CALL NUMBER (6.1,1.75,0.14,TOQGWE,0.0,-1)
        CALL SYMBOL (2.0,2.00,0.14,TOTAL,0.0,16)
        CALL NUMBER (5.1,2.00,0.14,TOQUAN,0.0,3)
        CALL SYMBOL (5.85,2.00,0.14,69,0.0,-1)
        CALL NUMBER (6.1,2.00,0.14,TOTQE,0.0,-1)
        CALL SYMBOL (6.7,1.75,0.14,CF,0.0,20)
        CALL NUMBER (7.6,1.75,0.14,TOTGWI,0.0,2)
        CALL SYMBOL (6.7,2.00,0.14,CF,0.0,20)
        CALL NUMBER (7.6,2.00,0.14,TOTQIN,0.0,2)
        GO TO 8
 6      CALL SYMBOL (2.0,4.75,0.14,RECHAR,0.0,16)
        CALL NUMBER (4.5,4.75,0.14,RECHG,0.0,-1)
        CALL SYMBOL (6.5,4.75,0.14,GPD,0.0,12)
        CALL SYMBOL (2.0,5.00,0.14,GROUNP,0.0,20)
        CALL NUMBER (5.1,5.00,0.14,PERCEN,0.0,1)
        CALL SYMBOL (2.0,5.25,0.14,GROUND,0.0,24)
        CALL NUMBER (5.1,5.25,0.14,TOQUGW,0.0,3)
        CALL SYMBOL (5.85,5.25,0.14,69,0.0,-1)
        CALL NUMBER (6.1,5.25,0.14,TOQGWE,0.0,-1)
        CALL SYMBOL (2.0,5.50,0.14,TOTAL,0.0,16)
        CALL NUMBER (5.1,5.50,0.14,TOQUAN,0.0,3)
        CALL SYMBOL (5.85,5.50,0.14,69,0.0,-1)
        CALL NUMBER (6.1,5.50,0.14,TOTQE,0.0,-1)
        CALL SYMBOL (6.7,5.25,0.14,CF,0.0,20)
        CALL NUMBER (7.6,5.25,0.14,TOTGWI,0.0,2)
        CALL SYMBOL (6.7,5.50,0.14,CF,0.0,20)
        CALL NUMBER (7.6,5.50,0.14,TOTQIN,0.0,2)
        GO TO 8
 7      CALL SYMBOL (2.0,1.25,0.14,RECHAR,0.0,16)
        CALL NUMBER (4.5,1.25,0.14,RECHG,0.0,-1)
```

```
      CALL SYMBOL (6.5,1.25,0.14,GPD,0.0,12)
      CALL SYMBOL (2.0,1.50,0.14,GROUNP,0.0,20)
      CALL NUMBER (5.1,1.50,0.14,PERCEN,0.0,1)
      CALL SYMBOL (2.0,5.25,0.14,GROUND,0.0,24)
      CALL NUMBER (5.1,5.25,0.14,TOQUGW,0.0,3)
      CALL SYMBOL (5.85,5.25,0.14,69,0.0,-1)
      CALL NUMBER (6.1,5.25,0.14,TOQGWE,0.0,-1)
      CALL SYMBOL (2.0,5.50,0.14,TOTAL,0.0,16)
      CALL NUMBER (5.1,5.50,0.14,TOQUAN,0.0,3)
      CALL SYMBOL (5.85,5.50,0.14,69,0.0,-1)
      CALL NUMBER (6.1,5.50,0.14,TOTQE,0.0,-1)
      CALL SYMBOL (6.7,5.25,0.14,CF,0.0,20)
      CALL NUMBER (7.6,5.25,0.14,TOTGWI,0.0,2)
      CALL SYMBOL (6.7,5.50,0.14,CF,0.0,20)
      CALL NUMBER (7.6,5.50,0.14,TOTQIN,0.0,2)
8     CONTINUE
      CALL SYMBOL (1.000,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (1.317,6.050,0.07,'OCT',0.0,3)
      CALL SYMBOL (1.775,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (2.525,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (3.300,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (3.617,6.050,0.07,'JAN',0.0,3)
      CALL SYMBOL (4.075,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (4.775,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (5.550,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (5.867,6.050,0.07,'APR',0.0,3)
      CALL SYMBOL (6.300,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (7.075,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (7.825,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (8.142,6.050,0.07,'JUL',0.0,3)
      CALL SYMBOL (8.600,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (9.375,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (9.692,6.050,0.07,'SEP',0.0,3)
      CALL SYMBOL (10.125,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (1.,6.5,0.14,TECH,0.,24)
      CALL SYMBOL (1.,7.,.14,TITLE,0.0,64)
      CALL NUMBER (9.25,6.5,0.14,DRA,0.0,1)
      CALL SYMBOL (10.25,6.5,0.14,'SQ.MI.',0.0,6)
      IF(NMISS.GT.0) GO TO 9
      CALL PLOT (12.0,0.0,-3)
      CALL PLOTE2
      RETURN
9     RMISS=FLOAT(NMISS)
      CALL NUMBER (6.5,6.5,0.14,RMISS,0.0,-1)
      CALL SYMBOL (7.0,6.5,0.14,' MISSING DAYS',0.0,13)
      CALL PLOT (12.0,0.0,-3)
      CALL PLOTE2
      RETURN
      END
      SUBROUTINE PUNCHR
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      WRITE (7,2) STA,DRA
      TOTDIS=.0
      TOTGW=0.0
      DO 1 I=1,365
      IF(DSS(I).LT.0.0) GO TO 1
      TOTDIS=TOTDIS+DSS(I)
      TOTGW=TOTGW+GDIS(I)
1     CONTINUE
      TOQUAN=86400.*TOTDIS
      TOQUGW=86400.*TOTGW
      TOTGWI=0.03719*(TOTGW/DRA)
      TOTQIN=0.03719*(TOTDIS/DRA)
      TDISMI=TOQUAN/DRA
      TDGWSM=TOQUGW/DRA
      PERCEN=(TOQUGW/TOQUAN)*100.
      RECH=TDGWSM*7.48/365.
      IRECH=IFIX(RECH/1000.)
```

```
      RECHG=FLOAT(IRECH*1000)
      IF(RECH.LE.10000) RECHG=RECH
      WRITE (7,3) TOQUAN,TOQUGW,TOTQIN,TOTGWI,PERCEN,RECHG
      WRITE (7,4) GDIS
      RETURN
C
C
 2    FORMAT (16A4,F8.2)
 3    FORMAT (E10.3,E10.3,F7.2,F7.2,F5.1,F9.0)
 4    FORMAT (10(F8.0))
      END
      SUBROUTINE FLWDUR
      INTEGER PER(365),PLOT(101,120),DOT,PLUS,BLANK,CAPI
      DIMENSION DISDEN(365), INDX(365), APER(365)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA BLANK/'    '/,PLUS/'++++'/,DOT/'....'/,CAPI/'IIII'/
      WRITE (6,16) STA,DRA
      M=365-1
      DO 2 I=1,M
      L=365-1
      DO 1 J=1,L
      IF(DSS(J).LE.DSS(J+1)) GO TO 1
      X=DSS(J)
      DSS(J)=DSS(J+1)
      DSS(J+1)=X
 1    CONTINUE
 2    CONTINUE
      DO 7 I=1,101
      DO 3 J=1,120
      PLOT(I,J)=BLANK
 3    CONTINUE
      PLOT(I,120)=CAPI
      IF(I/2.-I/2) 4,4,5
 4    PLOT(I,18)=DOT
      PLOT(I,36)=DOT
      PLOT(I,54)=DOT
      PLOT(I,60)=DOT
      PLOT(I,78)=DOT
      PLOT(I,96)=DOT
      PLOT(I,114)=DOT
 5    CONTINUE
      IF(I.EQ.1) GO TO 7
      IF(I.EQ.101) GO TO 7
      IF(MOD(I,10).NE.1) GO TO 7
      DO 6 J=2,118,2
      PLOT(I,J)=DOT
 6    CONTINUE
 7    CONTINUE
      DO 8 I=1,365
      APER(I)=(365-I+1.)*100/365
      PER(I)=IFIX((365-I+1.)*100/365+.5)
      DISDEN(I)=DSS(I)/DRA
      IF(DISDEN(I).LE..1) GO TO 8
      INDX(I)=IFIX(60.*ALOG10(DISDEN(I))+60.5)
      IF(INDX(I).GT.120) GO TO 8
      PLOT(PER(I)+1,INDX(I))=PLUS
 8    CONTINUE
      WRITE (6,17)
      WRITE (6,18)
      WRITE (6,19)
      DO 10 I=1,101
      KI=I-1
      IF(I.GT.1) GO TO 9
      WRITE (6,20) KI,(PLOT(I,J),J=1,120)
      GO TO 10
 9    WRITE (6,21) KI,(PLOT(I,J),J=1,120)
 10   CONTINUE
      WRITE (6,22)
```

```
      WRITE (6,16) STA,DRA
      WRITE (6,23)
      DO 11 I=1,365,8
      IF(I.EQ.361) GO TO 12
      II=I+7
      WRITE (6,24) (APER(N),DISDEN(N),N=I,II)
 11   CONTINUE
 12   WRITE (6,25) (APER(N),DISDEN(N),N=361,365)
      DELTA1=DISDEN(37)-DISDEN(36)
      DELTA2=DISDEN(329)-DISDEN(328)
      DELTA3=DISDEN(92)-DISDEN(91)
      DELTA4=DISDEN(274)-DISDEN(273)
      Q90=DISDEN(36)+(DELTA1/2)
      Q10=DISDEN(328)+(DELTA2/2)
      Q75=DISDEN(91)+(DELTA3/4)
      Q25=DISDEN(274)-(DELTA4/4)
      IF(Q90.LE.0.) GO TO 13
      IF(Q75.LE.0.) GO TO 14
      GO TO 15
 13   WRITE (6,27)
      IF(Q90.LE.0.) Q90=0.001
      GO TO 15
 14   WRITE (6,28)
      IF(Q75.LE.0.) Q75=0.001
      GO TO 15
 15   RT1090=SQRT(Q10/Q90)
      RT2575=SQRT(Q25/Q75)
      WRITE (6,26) RT1090,RT2575
      RETURN
C
C
 16   FORMAT ('1','FLOW-DURATION CURVE FOR',17X,16A4,2X,F8.2,2X,'SQ.MI')
 17   FORMAT ('0','PERCENT',48X,'FLOW CFS/SQ MI')
 18   FORMAT ('0',2X,'TIME',3X,'.1',16X,'.2',16X,'.4',16X,'.8',3X,'1.0',
     116X,'2',17X,'4',17X,'8',4X,'10')
 19   FORMAT ('0',9X,2('*',17('-'),'*',17('-'),'*',17('-'),'*',5('-')),'
     1*')
 20   FORMAT ('+',4X,I3,2X,'I',120A1)
 21   FORMAT (' ',4X,I3,2X,'I',120A1)
 22   FORMAT ('+',9X,2('*',17('-'),'*',17('-'),'*',17('-'),'*',5('-')),'
     1*')
 23   FORMAT ('0')
 24   FORMAT (' ',4X,8(F6.2,1X,F6.3,3X))
 25   FORMAT (' ',4X,5(F6.2,1X,F6.3,3X))
 26   FORMAT ('0',7X,'THE RATIO (Q10/Q90)**1/2 =',F8.2,10X,'(Q25/Q75)**1
     11/2 =',F8.2)
 27   FORMAT (' ',' Q90 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANINGL
     1ESS.')
 28   FORMAT (' ','   Q75 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANIN
     1GLESS.')
      END
      SUBROUTINE HYDGRH
C      * * THIS SUBROUTINE WRITES OUT THE HYDROGRAPH WITH THE
C          DISCHARGE SHOWN AS PLUSES AND THE GROUND WATER SEPARATION
C          AS ASTERIKS
C     WRITES OUT HYDROGRAPH
C
      INTEGER PLUS,DOT,AST
      DIMENSION MON(365), MAP(120)
      REAL MDIS,LMIN,LMAX
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA BLANK/'    '/,PLUS/'++++'/,DOT/'....'/,AST/'****'/
      DO 1 I=1,365
      MON(I)=BLANK
 1    CONTINUE
C     FIRST, STATION NUMBER AND DRAINAGE AREA
      WRITE (6,10) STA,DRA
C     THEN LABELS
```

```
      WRITE (6,11)
C     THIS IS THE LOG SCALE OF THE HYDROGRAPH
      WRITE (6,12)
      WRITE (6,13)
      DO 8 I=1,365
      IF(DSS(I).LE.0.01) DSS(I)=0.01
      IF(GDIS(I).LE.0.01) GDIS(I)=0.01
      DO 2 J=1,119
C
C     MAP= ONE OUTPUT LINE OF THE HYDROGRAPH
C     THIS SECTION CREATES BASIC GRAPH OUTLINE
C
  2   MAP(J)=BLANK
      MAP(120)=PLUS
      IF(MON(I).NE.DOT) GO TO 4
      IF(I.EQ.365) GO TO 4
      DO 3 KI=2,118,2
  3   MAP(KI)=DOT
  4   CONTINUE
      IF(I/2.-I/2) 5,5,6
  5   MAP(40)=DOT
      MAP(80)=DOT
  6   CONTINUE
C
C     THIS SECTION ASSIGNS THE DISCHARGE VALUE A POINT ON THE GRAPH AND
C     OUTPUTS THAT DAY
      IF(DSS(I).LT.0.10) GO TO 7
C     ON THE GRAPH 20 SPACES= 1 LOG CYCLE AND THE LINE STARTS AT -1 LOG
C     CYCLE
      DLOG=20.*ALOG10(DSS(I))+20.
      IF(GDIS(I).LE.0.0) GO TO 7
      GLOG=20.*ALOG10(GDIS(I))+20.
C     THIS STATEMENT ''ROUNDS OFF'' VALUES TO THE NEAREST PRINT POSITION
      INDX=IFIX(2.*(DLOG-IFIX(DLOG))+IFIX(DLOG))
      INDXG=IFIX(2.*(GLOG-IFIX(GLOG))+IFIX(GLOG))
      MAP(INDX)=PLUS
      MAP(INDXG)=AST
  7   WRITE (6,14) MON(I),MAP,DSS(I)
  8   CONTINUE
C
C     ...AND SOME FINAL LABELS
      WRITE (6,15)
      WRITE (6,12)
C
C     THIS PART OF THE PROGRAM CALCULATES AND PRINTS OUT THE SUMMARY
C     LMIN= MINIMUM DISCHARGE
C     LMAX= MAXIMUM DISCHARGE
C     TOQUAN= TOTAL DISCHARGE IN A YEAR
C     MDIS= MEAN DISCHARGE
      DAYS=0.0
      LMIN=100000.
      LMAX=.0
      TOTDIS=.0
      TOTGW=0.0
      DO 9 I=1,365
      IF(DSS(I).LT.0.0) GO TO 9
      DAYS=DAYS+1.
      TOTDIS=TOTDIS+DSS(I)
      TOTGW=TOTGW+GDIS(I)
      IF(DSS(I).LT.LMIN) LMIN=DSS(I)
      IF(DSS(I).GT.LMAX) LMAX=DSS(I)
  9   CONTINUE
      TOQUAN=86400.*TOTDIS
      TOQUGW=86400.*TOTGW
      MDIS=TOTDIS/DAYS
      WRITE (6,16)
      WRITE (6,17) TOQUAN
      WRITE (6,18) LMIN
```

```
      WRITE (6,19) MDIS
      WRITE (6,20) LMAX
      TDISMI=TOQUAN/DRA
      TDGWSM=TOQUGW/DRA
      WRITE (6,21) TDISMI
      WRITE (6,22) TOQUGW
      WRITE (6,23) TDGWSM
      PERCEN=(TOQUGW/TOQUAN)*100.
      WRITE (6,24) PERCEN
      RECH=TDGWSM*7.48/DAYS
      WRITE (6,25) RECH
C
      RETURN
C
C
 10   FORMAT ('0',40X,16A4,2X,F8.2,2X,'SQ.MI')
 11   FORMAT ('0','MONTH',53X,'DISCHARGE, IN CFS')
 12   FORMAT ('0',4X,'.1',18X,'1',18X,'10',17X,'100',15X,'1,000',14X,'10
     1,000',13X,'100,000')
 13   FORMAT ('0',4X,'*',6(19('+'),'*'))
 14   FORMAT (' ',A4,'+',120A1,F7.1)
 15   FORMAT (' ',4X,'*',6(19('+'),'*'))
 16   FORMAT ('0')
 17   FORMAT ('0','TOTAL DISCHARGE FOR THE WATER YEAR',3X,E10.3,1X,'CF')
 18   FORMAT ('0','MINIMUM DISCHARGE',22X,F8.2,1X,'CFS')
 19   FORMAT ('0','MEAN DISCHARGE',25X,F8.2,1X,'CFS')
 20   FORMAT ('0','MAXIMUM DISCHARGE',22X,F8.2,1X,'CFS')
 21   FORMAT ('0','TOTAL DISCHARGE/YR/BASIN AREA',8X,E10.3,1X,'CF/SQ.MI'
     1)
 22   FORMAT ('0','THE TOTAL GROUND WATER DISCHARGE FOR A YEAR',2X,E10.3
     1,1X,'CF ')
 23   FORMAT ('0','TOTAL GROUND WATER DISCHARGE/YR/BASIN AREA',8X,E10.3,
     11X,'CF /SQMI')
 24   FORMAT ('0','% OF TOTAL DISCHARGE DUE TO GROUND WATER RUNOFF',F7.2
     1)
 25   FORMAT ('0',60X,'THE RECHARGE RATE  = ',E10.3,'   GPD/SQ.MI.')
      END
      SUBROUTINE NDTRI (P,X,D,IE)
C        SEE FORTRAN SSP FOR COMPLETE WRITEUP...
      IE=0
      X=.99999E+74
      D=X
      IF(P) 1,3,2
 1    IE=-1
      GO TO 10
 2    IF(P-1.0) 5,4,1
 3    X=-.99999E+74
 4    D=0.0
      GO TO 10
 5    D=P
      IF(D-0.5) 7,7,6
 6    D=1.0-D
 7    T2=ALOG(1.0/(D*D))
      T=SQRT(T2)
      X=T-(2.515517+0.802853*T+0.010328*T2)/(1.0+1.432788*T+0.189269*T2+
     10.001308*T2)
      IF(P-0.5) 8,8,9
 8    X=-X
 9    D=0.3989423*EXP(-X*X/2.0)
 10   RETURN
      END
      SUBROUTINE VFLWDA
C        THIS SUBROUTINE CALCULATES A FLOW DURATION CURVE FOR
C        THE YEAR AND PRINTS IT OUT ON THE VERSATEC PLOTTER.
C        ON LOGRITHMIC-PROBABILITY PAPER...
      DIMENSION DISDEN(365), INDX(365), APER(365), DIS(365)
      DIMENSION AY(46), AX(23), DDS(365)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
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      DATA AX/.001,.002,.005,.01,.02,.05,.1,.2,.25,.30,.40,.50,.60,.70,.
     175,.80,.90,.95,.98,.99,.995,.998,.999/
      DATA AY/.001,.002,.003,.004,.005,.006,.007,.008,.009,.01,.02,.03,.
     104,.05,.06,.07,.08,.09,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.,2.,3.,4.,5.,6
     2.,7.,8.,9.,10.,20.,30.,40.,50.,60.,70.,80.,90.,100./
       NCNT=1
      RNCNT=FLOAT(NCNT)
C         THIS SECTION CREATES THE BASIC GRAPH OUTLINE...
      CALL PLOT (1.0,1.0,-3)
      CALL SYMBOL (0.0,-1.0,0.14,'PERCENT OF TIME DISCHARGE IS EQUALLED
     1OR EXCEEDED',0.0,49)
      CALL SYMBOL (-1.0,1.0,0.14,'DISCHARGE IN CFS/MI 2',90.0,21)
      DO 5 I=1,46
      YPLOT=(ALOG10(AY(I))*2.25)+6.75
      IF(AY(I).LT.0.01) GO TO 1
      IF(AY(I).LT.0.10) GO TO 2
      IF(AY(I).LT.1.00) GO TO 3
      CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,-1)
      GO TO 4
    1 CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,3)
      GO TO 4
    2 CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,2)
      GO TO 4
    3 CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,1)
    4 CALL PLOT (0.3,YPLOT,3)
      CALL PLOT (9.6,YPLOT,2)
    5 CONTINUE
      DO 8 I=1,23
      CALL NDTRI (AX(I),X,D,IER)
      XPLOT=5.0+X*1.5
      IF(AX(I).LT.0.1.OR.AX(I).GT.0.99) GO TO 6
      CALL NUMBER ((XPLOT-0.07),-0.4,0.07,(100.*AX(I)),0.0,-1)
      GO TO 7
    6 CALL NUMBER ((XPLOT-0.07),-0.4,0.07,(100.*AX(I)),0.0,1)
    7 CALL PLOT (XPLOT,0.0,3)
      CALL PLOT (XPLOT,11.3,2)
    8 CONTINUE
      NMISS=0
      NOFLOW=0
      MMM=0
      NNM=0
C         DATA SCAN FOR POSSIBLE MISSING DATA OR NO FLOW (<0.01)
      DO 10 I=1,365
      IF(DSS(I).LT.0.0) GO TO 9
      IF(DSS(I).LT.0.01) NOFLOW=NOFLOW+1
      NNM=NNM+1
      DDS(NNM)=DSS(I)
      GO TO 10
    9 NMISS=NMISS+1
   10 CONTINUE
      MMM=MMM+NNM
      M=NNM-1
      DO 12 I=1,M
      L=NNM-1
      DO 11 J=1,L
      IF(DDS(J).LE.DDS(J+1)) GO TO 11
      XR=DDS(J)
      DDS(J)=DDS(J+1)
      DDS(J+1)=XR
   11 CONTINUE
   12 CONTINUE
      DAYS=FLOAT(NNM)
      DO 13 I=1,NNM
      APER(I)=(NNM-I+1.)*100/NNM
      DISDEN(I)=DDS(I)/DRA
   13 CONTINUE
C         WRITES OUT FLOW DURATION TABLE
      WRITE (6,30) STA,DRA
```

```
      DO 14 I=1,NNM,8
      IF(NNM.EQ.365.AND.I.EQ.361) GO TO 15
      II=I+7
      WRITE (6,32) (APER(N),DISDEN(N),N=I,II)
   14 CONTINUE
      GO TO 19
   15 WRITE (6,33) (APER(N),DISDEN(N),N=361,365)
      DELTA1=DISDEN(37)-DISDEN(36)
      DELTA2=DISDEN(329)-DISDEN(328)
      DELTA3=DISDEN(92)-DISDEN(91)
      DELTA4=DISDEN(274)-DISDEN(273)
      Q90=DISDEN(36)+(DELTA1/2)
      Q10=DISDEN(328)+(DELTA2/2)
      Q75=DISDEN(91)+(DELTA3/4)
      Q25=DISDEN(274)-(DELTA4/4)
      IF(Q90.LE.0.) GO TO 16
      IF(Q75.LE.0.) GO TO 17
      GO TO 18
   16 WRITE (6,35)
      IF(Q90.LE.0.) Q90=0.001
      IF(Q75.NE.0.0) GO TO 18
   17 WRITE (6,36)
      IF(Q75.LE.0.) Q75=0.001
      GO TO 18
   18 RT1090=SQRT(Q10/Q90)
      RT2575=SQRT(Q25/Q75)
      WRITE (6,34) RT1090,RT2575
   19 CONTINUE
C     GRAPHS CURVES ON LOG-PROBABILITY SCALE
      INDEX1=NNM/3
      INDEX2=INDEX1*2
      DO 20 I=1,NNM
      DAS=DDS(I)/DRA
      IF(DAS.LT.0.001) DAS=0.001
      YY=(ALOG10(DAS)*2.25)+6.75
      IC=2
      IF(I.EQ.1) IC=3
      XPER=APER(I)/100.
      IF(XPER.GE.1.0) XPER=.999
      IF(XPER.LE.0.001) XPER=.001
      CALL NDTRI (XPER,X,D,IER)
      IF(IER.NE.0) WRITE (6,31)
      XX=5.0+X*1.5
      IF(I.EQ.1) CALL NUMBER ((XX+0.02),YY,0.07,RNCNT,0.0,-1)
      CALL PLOT (XX,YY,IC)
      IF(I.EQ.INDEX1) CALL SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(I.EQ.INDEX2) CALL SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(XPER.GT.0.95.OR.XPER.LT.0.05) CALL SYMBOL (XX,YY,0.035,1,0.0,-1
     1)
   20 CONTINUE
      CALL NUMBER ((XX-0.07),YY,0.07,RNCNT,0.0,-1)
      IF(NOFLOW.GT.0) GO TO 21
      GO TO 24
C     INDICATES POSITION OF LAST NO FLOW WITH AN ASTERISK(IF NOFLOW>0)
   21 DO 23 I=1,NNM
      IF(DDS(I).GT.0.01) GO TO 23
      IF(DDS(I).LT.0.01.AND.DDS(I+1).GT.0.01) GO TO 22
      GO TO 23
   22 XPER=APER(I)/100.
      IF(XPER.LE.0.001) XPER=.001
      CALL NDTRI (XPER,X,D,IER)
      XX=5.0+X*1.5
      CALL SYMBOL (XX,-0.10,0.14,11,0.0,-1)
   23 CONTINUE
C        WRITES SUMMARY INFORMATION AT TOP OF PAGE FOR EACH CURVE
   24 CONTINUE
      CALL NUMBER (0.5,13.25,0.14,RNCNT,0.0,-1)
      CALL SYMBOL (1.0,13.25,0.14,STA,0.0,64)
```

```
      XPL=0.0
      GO TO 25
 25   CALL NUMBER ((XPL+0.5),12.5,0.14,RNCNT,0.0,-1)
      CALL NUMBER (XPL,12.25,0.07,DAYS,0.0,-1)
      CALL SYMBOL ((XPL+0.28),12.25,0.07,'DAYS PLOTTED',0.0,12)
      IF(NMISS.GT.0) GO TO 26
      IF(NOFLOW.GT.0) GO TO 27
      GO TO 28
 26   RMISS=FLOAT(NMISS)
      CALL NUMBER (XPL,12.0,0.07,RMISS,0.0,-1)
      CALL SYMBOL ((XPL+0.28),12.0,0.07,' DAYS MISSING DATA',0.0,18)
      IF(NOFLOW.EQ.0) GO TO 28
 27   ROFLOW=FLOAT(NOFLOW)
      CALL NUMBER (XPL,11.75,0.07,ROFLOW,0.0,-1)
      CALL SYMBOL ((XPL+0.28),11.75,0.07,' DAYS NO FLOW(*)',0.0,16)
 28   IF(NNM.NE.365) GO TO 29
      CALL SYMBOL (XPL,11.5,0.07,'(Q 10 /Q 90 ) 1/2 =',0.0,19)
      CALL NUMBER ((XPL+1.75),11.5,0.07,RT1090,0.0,2)
      CALL SYMBOL (XPL,11.30,0.07,'(Q 25 /Q 75 ) 1/2 =',0.0,19)
      CALL NUMBER ((XPL+1.75),11.30,0.07,RT2575,0.0,2)
      CALL PLOTE2
 29   RETURN
C
C
 30   FORMAT ('1','FLOW-DURATION CURVE FOR',17X,16A4,2X,F8.2,2X,'SQ.MI')
 31   FORMAT ('0',' * * * * * * * * * * * W A R N I N G  ERROR IN NDTRI')
 32   FORMAT (' ',4X,8(F6.2,1X,F6.3,3X))
 33   FORMAT (' ',4X,5(F6.2,1X,F6.3,3X))
 34   FORMAT ('0',7X,'THE RATIO (Q10/Q90)**1/2 =',F8.2,10X,'(Q25/Q75)**1
     1/2 =',F8.2)
 35   FORMAT (' ',' Q90 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANINGL
     1ESS.')
 36   FORMAT (' ','   Q75 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANIN
     1GLESS.')
      END
C********** QUARTIO ************************
C     THIS PROGRAM PLOTS TWO CHOSEN PARAMETERS AGAINST EACH OTHER AND
C     CALCULATES THE 2 REGRESSION EQUATIONS AND THE COEFFICIENT OF
C     CORRELATION
      DIMENSION HEAD(20), CONST(2,400), PARAM(366,19)
      DIMENSION R(19,19)
      DIMENSION LABEL(19)
      INTEGER*4 CONST
      DATA LABEL(1)/'QCFS'/,LABEL(2)/'TEMP'/,LABEL(3)/'COND'/,LABEL(4)/'
     1 PH '/,LABEL(5)/' SI '/,LABEL(6)/' CA '/,LABEL(7)/' MG '/,LABEL(8)
     2/' NA '/,LABEL(9)/'  K '/,LABEL(10)/'HCO3'/,LABEL(11)/' SO4'/,LABE
     3L(12)/' CL '/,LABEL(13)/'  F '/,LABEL(14)/' NO3'/,LABEL(15)/' DS '
     4/,LABEL(16)/'HARD'/,LABEL(17)/' FE '/,LABEL(18)/' MN '/,LABEL(19)/
     5'QLOG'/
      DATA THRESH/0.9/
C     THE CHEMICAL PARAMETERS AND THEIR CORRESPONDING NUMBERS ARE
C     DISCHARGE-1, TEMPERATURE-2, SPECIFIC CONDUCTANCE-3, PH-4, SILICON-
C     CALCIUM-6, MAGNESIUM-7, SODIUM-8, POTASSIUM-9, BICARBONATE-10,
C     SULFATE-11, CHLORIDE-12, FLOURIDE-13,NITRATE-14,DISSOLVED SOLIDS-1
C     HARDNESS-16, IRON-17, MANGANESE-18.
C     THE CHEMICAL DATA ARE ENTERED AS FOLLOWS- Q IN COLS 1-5 RIGHT
C     JUSTIFIED. THIS MUST BE INSTANTANEOUS DISCHARGE. TEMP IN COLS 6-9,
C     USE DECIMAL PT AND ONE PLACE TO THE RIGHT OF IT. CONDUCTANCE IN CO
C     10-13, RIGHT JUSTIFIED (RJ), PH IN COLS 14-17, WITH A DEC PT & ONE
C     PLACE TO THE RIGHT OF IT. SI IN COLS 18-21, DEC PT & ONE PLACE TO
C     THE RIGHT. CA IN COLS 22-25 RJ, MAGNESIUM IN COLS 26-28 RJ. NA IN
C     COLS 29-32 RJ. K IN COLS 33-36 RJ. BICARBONATE IN COLS 37-40 RJ.
C     SULFATE IN COLS 41-44 RJ. CL IN COLS 45-48 RJ. F IN COLS 49-51,DEC
C     PT & ONE PLACE AFTER. NO3 IN COLS 52-56, DEC PT AND ONE PLACE AFTE
C     DISSOLVED SOLIDS IN COLS57-60 RJ. HARDNESS IN COLS 61-64 RJ. IRON
C     GIVEN IN MICROGRAMS/LITER IT SHOULD BE CONVERTED TO MILLIGRAMS/LIT
C     BY DIVIDING BY 1000. IT IS IN COLS 65-69 WITH A DEC PT AND TWO
C     PLACES AFTER. MANGANESE SHOULD SIMILARLY BE PUT INTO MILLIGRAMS/
```

```
C      LITER AND PUT INTO COLS 70-74 WITH A DEC PT AND AND 2 PLACES AFTER
C      IT. ALL MISSING VALUES ARE ENTERED WITH  A -1.
C      THE LOG OF Q IS # 19 AND IS CALCULATED WITHIN THE PROGRAM
       INTEGER*4 CDTYPE(4),CARD(20),TYPE,XNAME,YNAME
       DATA CDTYPE/'DATA','RELA','RISO','RSUS'/
C   CARD-TYPE SYSTEM TO RECOGNIZE INPUT CARDS AND BRANCH ACCORDINGLY.
       CALL REREAD
 100   CONTINUE
       READ(5,306,END=300) CARD
 306   FORMAT(20A4)
       WRITE(6,307) CARD
 307   FORMAT(//,1X,20A4)
       READ(99,305) TYPE
 305   FORMAT(T15,A4)
       DO 301 I=1,4
       IF(TYPE.EQ.CDTYPE(I)) GO TO 302
 301   CONTINUE
       WRITE(6,108)
 108   FORMAT(' THE INPUT CARD PRINTED ABOVE IS NOT ONE OF THE ',
      X'ALLOWABLE STATEMENTS.'/,' THIS RUN IS THEREFORE ABORTED.')
       STOP
 302   CONTINUE
       GO TO (401,402,403,404),I
C
 401   CONTINUE
C   READ CHEMICAL DATA CARD DECK.
       CALL NORERD
C      READ IN THE HEADING
       READ (5,6) HEAD
C      READ IN THE # OF ANALYSES (QUALITY DATA CARDS)
       READ (5,9) NUMANL
C      READ IN CHEMICAL PARAMETERS
       DO 1 I=1,NUMANL
       READ (5,10) (PARAM(I,J),J=1,18)
       DO 1 K=1,18
       IF((PARAM(I,K)).LT.0.0) PARAM(I,K)=-1.0
 1     CONTINUE
C      COMPUTING LOG OF Q
       DO 3 I=1,NUMANL
       IF(PARAM(I,1).LE.0.0) GO TO 2
       PARAM(I,19)=ALOG10(PARAM(I,1))
       IF(PARAM(I,19).EQ.-1.0) PARAM(I,19)=-1.000001
       GO TO 3
 2     PARAM(I,19)=-1.
 3     CONTINUE
       CALL REREAD
       GO TO 100
C
 402   CONTINUE
C   CHANGE THE CORRELATION COEFFICIENT PLOT THRESHOLD TO (X.XX).
       READ(99,310) THRESH
 310   FORMAT(T55,F3.2)
       GO TO 100
C
 403   CONTINUE
C   PLOT ALL COMPARISONS WHOSE CORRELATION COEFFICIENT EXCEEDS THE THRESH
       CALL CORREL(NUMANL,PARAM,LABEL,R)
       DO 1000 I=1,19
       DO 101 J=1,19
       IF(J.LE.I) GO TO 101
       IF(R(I,J).EQ.-1.) GO TO 101
       IF(ABS(R(I,J)).GT.THRESH) CALL GRAPH(HEAD,NUMANL,I,J,LABEL,PARAM)
 101   CONTINUE
 1000   CONTINUE
       GO TO 100
C
 404   CONTINUE
C   PLOT (XXXX) VERSUS (YYYY).
```

```
      READ(99,311) XNAME,YNAME
 311  FORMAT(T7,A4,T21,A4)
C
C  FOR SPECIFICALLY REQUESTED PLOTS....
      DO 200 L=1,19
      IF(XNAME.EQ.LABEL(L)) GO TO 201
 200  CONTINUE
      WRITE(6,202) XNAME
 202  FORMAT(' X VARIABLE NAME ''',A4,''' IS NOT ONE OF THE '
     X,'ALLOWED NAMES. THE ABOVE CARD WILL BE IGNORED.')
      GO TO 100
 201  CONTINUE
      I=L
      DO 203 L=1,19
      IF(YNAME.EQ.LABEL(L)) GO TO 204
 203  CONTINUE
      WRITE(6,205) YNAME
 205  FORMAT(' Y VARIABLE NAME ''',A4,''' IS NOT ONE OF THE '
     X,'ALLOWED NAMES. THE ABOVE CARD WILL BE IGNORED.')
      GO TO 100
 204  CONTINUE
      J=L
      CALL GRAPH(HEAD,NUMANL,I,J,LABEL,PARAM)
C
      GO TO 100
C
 300  CONTINUE
      STOP
C
 6    FORMAT (20A4)
 9    FORMAT (I3)
 10   FORMAT (F5.0,F4.1,F4.0,2F4.1,F4.0,F3.0,5F4.0,F3.1,F5.1,2F4.0,2F5.2
     1)
      END
      SUBROUTINE GRAPH (HEAD,NUMANL,IN,JN,LABEL,PARAM)
C     HEAD IS AN ARRAY CONTAINING A HEADING (MAXIMUM OF 80 CHARACTERS)
C     NUMANL IS THE INTEGER NUMBER OF DATA POINTS
C     THE ARRAYS X AND Y CONTAIN THE COORDINATES OF THE NUMANL DATA
C  POINTS.
C     XO, YO, ARE THE REAL COORDINATES OF THE LOWER LEFT CORNER OF THE
C       GRAPH
C     DX AND DY ARE THE NUMBER OF UNITS/INCH ALONG THE X AND Y AXES
      DIMENSION GRAF(76,51), RLABEL(6), CLABEL(6), X(366), Y(366)
      DIMENSION HEAD(20)
      DIMENSION LABEL(19),PARAM(366,19)
      INTEGER XNAME,YNAME
      DATA HORIZO,VERT,PLUS,BLANK,EX,AST/'-','|','+',' ','X','*'/
C     THIS SECTION FINDS THE MAXIMA AND MINIMA AND CONSTRUCTS THE SCALE
      XMAX=0.0
      XMIN=10000.0
      YMAX=0.0
      YMIN=10000.0
      DO 4 I=1,NUMANL
      X(I)=PARAM(I,IN)
      Y(I)=PARAM(I,JN)
      IF(X(I).GE.XMAX) XMAX=X(I)
      IF(Y(I).GE.YMAX) YMAX=Y(I)
      IF((X(I).LT.XMIN).AND.(X(I).GE.0.0)) XMIN=X(I)
      IF((Y(I).LT.YMIN).AND.(Y(I).GE.0.0)) YMIN=Y(I)
 4    CONTINUE
      XO=XMIN
      YO=YMIN
      DX=(XMAX-XMIN)/5.0
      DY=(YMAX-YMIN)/5.0
      XNAME=LABEL(IN)
      YNAME=LABEL(JN)
      SUMX=0.0
      SUMY=0.0
```

```
      SUMXY=0.0
      SUMXSQ=0.0
      SUMYSQ=0.0
      WRITE (6,22) HEAD
C
C
C     THIS SECTION PRINTS UP BASIC GRAPH***
      DO 1 I=2,50
      GRAF(1,I)=VERT
      GRAF(76,I)=VERT
 1    CONTINUE
      DO 2 I=2,75
      GRAF(I,1)=HORIZO
      GRAF(I,51)=HORIZO
 2    CONTINUE
      DO 3 I=1,6
      IJ=1+(I-1)*10
      GRAF(1,IJ)=PLUS
      GRAF(76,IJ)=PLUS
 3    CONTINUE
      DO 40 I=1,6
      IJ=1+(I-1)*15
      GRAF(IJ,1)=PLUS
      GRAF(IJ,51)=PLUS
 40    CONTINUE
      DO 5 I=2,75
      DO 5 J=2,50
      GRAF(I,J)=BLANK
 5    CONTINUE
C     *************************************************
C
C
C     CHECK HERE FOR VARIOUS ERRORS***
      IF(NUMANL.LT.1) GO TO 18
      IF((DX.LE.0.0).OR.(DY.LE.0.0)) GO TO 19
C     *************************************************
C
C
C     CALCULATE REGRESSION
      IMARK=0
      MARK=NUMANL
      DO 7 I=1,NUMANL
      IF((X(I).NE.-1.0).AND.(Y(I).NE.-1.0)) GO TO 6
      MARK=MARK-1
      IMARK=IMARK+1
      GO TO 7
 6    SUMX=X(I)+SUMX
      SUMY=Y(I)+SUMY
      SUMXSQ=(X(I))**2+SUMXSQ
      SUMYSQ=(Y(I))**2+SUMYSQ
      SUMXY=X(I)*Y(I)+SUMXY
 7    CONTINUE
      NEW=MARK
      DENOM=NEW*SUMXSQ-SUMX**2
      IF(DENOM.EQ.0.0) GO TO 17
      A=(SUMXSQ*SUMY-SUMX*SUMXY)/DENOM
      B=(NEW*SUMXY-SUMX*SUMY)/DENOM
C     ...AND STORE IN THE GRAPH
      DO 8 IX=2,75
      XVALU=(IX-1.0)*DX/15.0+XO
      YVALU=A+B*XVALU
      IY=(YVALU-YO)*10./DY+0.5
      IF((IY.GT.51).OR.(IY.LT.1)) GO TO 8
      JY=52-IY
      GRAF(IX,JY)=AST
 8    CONTINUE
      DENMP=NEW*SUMYSQ-SUMY**2
      IF(DENMP.EQ.0.0) GO TO 17
```

```
      AP=(SUMYSQ*SUMX-SUMY*SUMXY)/DENMP
      BP=(NEW*SUMXY-SUMX*SUMY)/DENMP
      DO 9 JY=1,51
      IY=52-JY
      YVALU=(IY-1.0)*DY/10.+YO
      XVALU=AP+BP*YVALU
      IX=(XVALU-XO)*15.0/DX+0.5
      IF((IX.GT.76).OR.(IX.LT.1)) GO TO 9
      GRAF(IX,JY)=PLUS
    9 CONTINUE
      R=SQRT(ABS(B*BP))*ABS(B)/B
C     **************************************************
C
C
C     PLOTTING THE DATA POINTS***
   10 KOUNT=0
      DO 12 I=1,NUMANL
      ICOLX=(X(I)-XO)*15.0/DX+0.5
      IROWY=(Y(I)-YO)*10./DY+0.5
      JCOLX=ICOLX+1
      JROWY=51-IROWY
      IF(((JCOLX.LE.76).AND.(JCOLX.GE.1)).AND.((JROWY.LE.51).AND.(JROWY.
     1GE.1))) GO TO 11
C     IN CASE PT IS OFF GRAPH:
      KOUNT=KOUNT+1
      GO TO 12
   11 GRAF(JCOLX,JROWY)=EX
C     ************************************************
C
C
C     MAKING LABELS AND PRINTING OUT GRAPH***
   12 CONTINUE
      DO 13 I=1,6
      CLABEL(I)=XO+DX*(I-1)
      RLABEL(I)=YO+DY*(6-I)
   13 CONTINUE
      DO 16 I=1,51
      DO 14 K=1,6
      IF(I.EQ.(1+10*(K-1))) GO TO 15
   14 CONTINUE
      WRITE (6,23) (GRAF(J,I),J=1,76)
      GO TO 16
   15 WRITE (6,24) RLABEL(K),(GRAF(J,I),J=1,76)
   16 CONTINUE
      WRITE (6,25) (CLABEL(I),I=1,6)
      WRITE (6,26) YNAME,XNAME
C     *****************************************************
C
C
C     PRINTING OUT:
C     # OF PTS OFF GRAPH
      KOUNT=KOUNT-IMARK
      WRITE (6,27) KOUNT
      WRITE (6,28) IMARK
C     THE REGRESSION EQUATION,
      IF(DENOM.EQ.0.0) GO TO 21
      IF(DENMP.EQ.0.0) GO TO 21
      WRITE (6,29) A,B
      WRITE (6,30) AP,BP
      WRITE (6,31) R
      GO TO 21
C     VARIOUS ERROR MESSAGES,
   17 WRITE (6,32)
      GO TO 10
   18 WRITE (6,33) NUMANL
      GO TO 21
   19 WRITE (6,34) DX,DY
      GO TO 21
```

```
C       AND A TABLE OF X & Y VALUES
 21     WRITE (6,37)
        WRITE(6,38)(XNAME,YNAME,J=1,4)
 38     FORMAT('0',4(1X,A4,6X,A4,14X),/)
        WRITE(6,39)(X(I),Y(I),I=1,NUMANL)
 39     FORMAT(4(1X,F7.2,3X,F7.2,11X))
        RETURN
C
 22     FORMAT ('1',20A4)
 23     FORMAT (' ',T23,76A1)
 24     FORMAT (' ',T10,F10.2,T23,76A1)
 25     FORMAT ('0',T17,6(F10.2,5X))
 26     FORMAT ('0',A4,2X,'VERSUS',2X,A4,/)
 27     FORMAT (' ','THE NUMBER OF POINTS OFF THE GRAPH AREA=',I4)
 28     FORMAT (' ',T10,'# OF MISSING DATA POINTS:',I4)
 29     FORMAT (' ',T30,'Y=',F12.4,' +',F12.4,'*X')
 30     FORMAT (' ',T30,'X=',F12.4,' +',F12.4,'*Y')
 31     FORMAT (' ',T10,'R=',F8.2)
 32     FORMAT ('0','REGRESSION CANNOT BE CALCULATED.')
 33     FORMAT ('0','NUMANL LESS THAN 1. NUMANL=',I4)
 34     FORMAT ('0','MISTAKE DX OR DY NOT POSITIVE. DX=',F10.2,' DY=',F10.
       12)
 37     FORMAT ('1',T50,'TABLE OF X AND Y VALUES')
        END
        SUBROUTINE CORREL(NUMANL,PARAM,LABEL,R)
C   THIS SUBROUTINE COMPUTES ALL CORRELATION COEFFICIENTS
C      AMONG THE PARAMETERS.
        DIMENSION PARAM(366,19),R(19,19),LABEL(19)
         LOGICAL*1 ABUF(132),BLANK(5)/5*' '/
        LOGICAL*1 MINUS1(5)/'-','1','.','0','0'/
        LOGICAL FRSTIM/.TRUE./
        IF(.NOT.FRSTIM) GO TO 100
        FRSTIM=.FALSE.
         DEFINE FILE 1(1,132,L,IREC)
        CALL CORBUF(1)
 100    CONTINUE
        WRITE(6,6)
 6      FORMAT(1H1,T50,'CORRELATION COEFFICIENT MATRIX',/)
        WRITE(6,7) LABEL
 7      FORMAT(8X,19(1X,A4,1X))
        DO 1 I=1,19
        DO 2 J=1,19
        SUMX=0.
        SUMY=0.
        SUMXY=0.
        SUMXSQ=0.
        SUMYSQ=0.
        MARK=NUMANL
        DO 3 K=1,NUMANL
        X=PARAM(K,I)
        Y=PARAM(K,J)
        IF(X.NE.-1.0.AND.Y.NE.-1.0) GO TO 60
        MARK=MARK-1
        GO TO 3
 60     CONTINUE
        SUMX=SUMX+X
        SUMY=SUMY+Y
        SUMXSQ=SUMXSQ+X*X
        SUMYSQ=SUMYSQ+Y*Y
        SUMXY=SUMXY+X*Y
 3      CONTINUE
        DENOM=MARK*SUMXSQ-SUMX*SUMX
        IF(DENOM.EQ.0.0) GO TO 17
        B=(MARK*SUMXY-SUMX*SUMY)/DENOM
        DENMP=MARK*SUMYSQ-SUMY*SUMY
        IF(DENMP.EQ.0.0) GO TO 17
        BP=(MARK*SUMXY-SUMX*SUMY)/DENMP
        IF(B.EQ.0.) GO TO 17
```

```
      R(I,J)=SQRT(ABS(B*BP))*ABS(B)/B
      GO TO 2
 17   CONTINUE
      R(I,J)=-1.
 2    CONTINUE
C  CONVERT PRINT LINE TO 'A' FORMAT.
      WRITE(1'1,50) LABEL(I),(R(I,J),J=1,19)
 50   FORMAT(1X,A4,1X,19(1X,F5.2))
      READ(1'1)ABUF
C  REPLACE '-1.00' WITH BLANKS WHEREVER IT OCCURS.
 52   CONTINUE
      CALL CMPARE(MINUS1(1),5,ABUF(1),132,IND)
      IF(IND.EQ.0) GO TO 51
      CALL INSERT(BLANK(1),0,ABUF(IND),5)
      GO TO 52
 51   CONTINUE
      WRITE(6,10) ABUF
 10   FORMAT('0',132A1)
 1    CONTINUE
      RETURN
      END
C********** STRHYDRO *************************
C THIS PROGRAM READS DAILY DISCHARGE AND PRINTS CURVE FOR EACH WATER YEA
C BY JOHN B MCKEON AND JACK TULLER 1/30/75
      INTEGER PLUS,DOT,BLANK
      DIMENSION STA(16),MON(365),MAP(120),DIS(365)
      DIMENSION MONSUB(12),MONTH(12)
      REAL MDIS,LMIN,LMAX
      DATA BLANK/'    '/,PLUS/'++++'/,DOT/'....'/
      DATA MON/365*'    '/
C
C     THIS SECTION MAKES THE MONTHLY LABELS
C
      DATA MONSUB/15,46,76,107,138,166,197,227,258,288,319,350/
      INTEGER DOTSUB(12)/31,61,92,123,151,182,212,243,273,304,335,365/
      DATA MONTH/'OCT ','NOV ','DEC ','JAN ','FEB ','MAR ','APR ',
     X'MAY ','JUN ','JUL ','AUG ','SEP '/
      DO 500 I=1,12
      MON(MONSUB(I))=MONTH(I)
      MON(DOTSUB(I))=DOT
 500  CONTINUE
C     READS THE STATION NAME AND NUMBER AND THE AREA OF THE BASIN
C
      READ(5,100) STA,DRA,N
 100  FORMAT(16A4,2X,F8.0,3X,I3)
      IF(N.NE.365) GO TO 7
C
C     READS IN DISCHARGE VALUES FROM CARDS
C
      READ(5,110) DIS
 110  FORMAT(10(F8.0))
      NOFLOW=0
      NMISS=0
      DMAX=0.0
      DO 1 I=1,365
      IF(DIS(I).GT.DMAX)DMAX=DIS(I)
      IF(DIS(I).EQ.0.)NOFLOW=NOFLOW+1
      IF(DIS(I).EQ.-1.) NMISS=NMISS+1
 1    CONTINUE
      IF(DMAX/DRA.GT.100.0) GO TO 9
C
C*****************************************
C
C     WRITES OUT HYDROGRAPH
C
C     FIRST, STATION NUMBER AND DRAINAGE AREA
      WRITE(6,200) STA,DRA
 200  FORMAT('1',40X,16A4,2X,F8.2,2X,'SQ.MI')
```

```
      IF(NOFLOW.GT.0) WRITE(6,2) NOFLOW
  2   FORMAT(' NOTE - THERE ARE ',I3,' DAYS OF NO FLOW.')
      IF(NMISS.GT.0) WRITE(6,3) NMISS
  3   FORMAT(' NOTE - THERE ARE ',I3,' DAYS OF MISSING DATA.')
C     THEN LABELS
      WRITE(6,210)
 210  FORMAT('0','MONTH',53X,'DISCHARGE, IN CFS')
C     THIS IS THE LOG SCALE OF THE HYDROGRAPH
      WRITE(6,220)
 220  FORMAT('0',4X,'.1',18X,'1',18X,'10'     ,17X,'100',15X,'1,000',14X,
     *'10,000',13X,'100,000')
      WRITE(6,230)
 230  FORMAT('0',4X,'*',6(19('+'),'*'))
      DO 300 I=1,365
      DO 250 J=1,119
C
C     MAP= ONE OUTPUT LINE OF THE HYDROGRAPH
C     THIS SECTION CREATES BASIC GRAPH OUTLINE
C
 250  MAP(J)=BLANK
      MAP(120)=PLUS
      IF(MON(I).NE.DOT)GO TO 270
      IF(I.EQ.365) GO TO 270
      DO 260 KI=2,118,2
 260  MAP(KI)=DOT
 270  CONTINUE
      IF(I/2.-I/2) 271,271,274
 271  MAP(40)=DOT
      MAP(80)=DOT
 274  CONTINUE
C
C     THIS SECTION ASSIGNS THE DISCHARGE VALUE A POINT ON THE GRAPH AND
C     OUTPUTS THAT DAY
      IF(DIS(I).LE..1) GO TO 275
C     ON THE GRAPH 20 SPACES= 1 LOG CYCLE AND THE LINE STARTS AT -1 LOG
C     CYCLE
      DLOG=20.*ALOG10(       DIS(I) )+20.
C     THIS STATEMENT ''ROUNDS OFF'' VALUES TO THE NEAREST PRINT POSITION
      INDX=DLOG+0.5
      IF(INDX.LT.1 .OR. INDX.GT.120) GO TO 275
      MAP(INDX)=PLUS
 275  WRITE(6,280) MON(I),MAP,DIS(I)
 280  FORMAT(' ',    A4,    '+',120A1,F7.1)
 300  CONTINUE
C
C     ...AND SOME FINAL LABELS
C
      WRITE(6,330)
      WRITE(6,220)
 330  FORMAT(' ',4X,'*',6(19('+'),'*'))
C
C THIS PART OF THE PROGRAM CALCULATES AND PRINTS OUT THE SUMMARY STATIST
C
C     LMIN= MINIMUM DISCHARGE
C     LMAX= MAXIMUM DISCHARGE
C     TOQUAN= TOTAL DISCHARGE IN A YEAR
C     MDIS= MEAN DISCHARGE
      LMIN=100000.
      LMAX=.0
      TOTDIS=.0
      DO 350 I=1,365
      TOTDIS=TOTDIS+DIS(I)
      IF(DIS(I).LT.LMIN) LMIN=DIS(I)
      IF(DIS(I).GT.LMAX) LMAX=DIS(I)
 350  CONTINUE
      TOQUAN=86400.*TOTDIS
      MDIS=TOTDIS/365.
      WRITE(6,215)
```

```
 215  FORMAT('0')
      WRITE(6,360)TOQUAN
 360  FORMAT('0','TOTAL DISCHARGE FOR THE WATER YEAR',3X,E10.3,1X,'CF')
      WRITE(6,370) LMIN
 370  FORMAT('0','MINIMUM DISCHARGE',22X,F8.2,1X,'CFS')
      WRITE(6,380) MDIS
 380  FORMAT('0','MEAN DISCHARGE',25X,F8.2,1X,'CFS')
      WRITE(6,390) LMAX
 390  FORMAT('0','MAXIMUM DISCHARGE',22X,F8.2,1X,'CFS')
      TDISMI=TOQUAN/DRA
      WRITE(6,215)
      WRITE(6,395) TDISMI
395   FORMAT('0','TOTAL DISCHARGE/YR/BASIN AREA',8X,E10.3,1X,'CF/SQ.MI')
C
C THIS PART SETS UP AND PRINTS THE DISCHARGE/AREA OF DRAINAGE BASIN CURV
C
      WRITE(6,200) STA,DRA
C     LABELS:
      WRITE(6,600)
 600  FORMAT('0','MONTH',42X,'DISCHARGE/AREA OF DRAINAGE BASIN,',
     *' CFS/SQ.MI')
C     LOG SCALE FOR GRAPH:
      WRITE(6,610)
610   FORMAT('0',4X,'.01',27X,'.10',27X,'1.0',27X,'10.0',26X,'100.0')
      WRITE(6,620)
620   FORMAT('0',4X,4('*',29('+')),'*')
C
C     THIS SECTION CREATES THE BASIC GRAPH OUTLINE
C
      DO 650 I=1,365
      DO 630 J=1,119
 630  MAP(J)=BLANK
      MAP(120)=PLUS
      IF(MON(I).NE.DOT) GO TO 635
      IF(I.EQ.365) GO TO 635
      DO 632 MI=2,118,2
 632  MAP(MI)=DOT
 635  CONTINUE
      IF(I/2.-I/2) 636,636,640
636   MAP(30)=DOT
      MAP(60)=DOT
      MAP(90)=DOT
 640  CONTINUE
C
C     THIS SECTION ASSIGNS NORMALIZED DISCHARGE VALUE A POINT ON THE
C     GRAPH AND OUTPUTS THAT DAY
      Y=DIS(I)/DRA
      IF(Y.LE..01)GO TO 645
C
C     THIS EXPANDED SCALE HAS 1 LOG CYCLE= 30 SPACES AND STARTS AT -2
C     LOG CYCLES
      X=30. * ALOG10(Y)+60.
      IF(X.GT.120.5) GO TO 645
C     THIS ''ROUNDS OFF'' VALUES TO THE NEAREST PRINT POSITION
      INDX=X+0.5
      IF(INDX.LT.1 .OR. INDX.GT.120) GO TO 645
      MAP(INDX)=PLUS
 645  WRITE(6,280) MON(I),MAP,DIS(I)
 650  CONTINUE
      WRITE(6,621)
621   FORMAT(' ',4X,4('*',29('+')),'*')
      WRITE(6,610)
400   STOP
 7    WRITE(6,6) N
 6    FORMAT('0','***** ERROR *****  N IS ',I3,'.  THIS PROGRAM IS DESIG
     *NED FOR WATER YEARS OF 365 DAYS'/'0',' BEGINNING IN OCTOBER.  PLEA
     *SE USE ANOTHER PROGRAM FOR OTHER TYPES OF RECORDS.')
      STOP
```

```
9     WRITE(6,8) DMAX,DRA                                                 00005760
8     FORMAT('0','***** ERROR *****  MAXIMUM DISCHARGE IS ',F10.0,'. DRA00005770
     *INAGE AREA IS ',F8.2,'.  '/'0','            THE RATIO DISCHARGE/DRA00005780
     *INAGE AREA EXCEEDS 100 CFS/SQ.MI.')                                 00005790
      STOP                                                                00005800
      END                                                                 00005810
C********** QUALDUR ***********************                                00005811
C     THIS PROGRAM PLOTS QUALITY DURATION CURVES FOR CHOSEN PARAMETERS    00005820
C     APRIL 1976                                                          00005830
C     HEAD IS THE HEADING CARD WITH STATION NUMBER AND NAME               00005840
C     PARAM IS THE ARRAY THAT STORES THE CHEMICAL DATA                    00005850
C     STORE IS THE ARRAY THAT COMPRESSES THE DATA SET, ELIMINATING GAPS   00005860
C     LABEL IS THE ARRAY OF THE  18 CONSTITUENT NAMES                     00005870
C     PCT IS THE ARRAY OF THE % EXCEEDED OR EQUALLED FOR EACH CHEMICAL    00005880
C     READING                                                             00005890
C     INDEX IS THE ARRAY THAT RECORDS THE CODE NUMBERS OF THE CHEMICAL    00005900
C     CONSTITUENTS FOR WHICH CURVES ARE DESIRED                           00005910
C     THE CHEMICAL PARAMETERS AND THEIR CORRESPONDING NUMBERS ARE         00005920
C     DISCHARGE-1, TEMPERATURE-2, SPECIFIC CONDUCTANCE-3, PH-4, SILICON-00005930
C     CALCIUM-6, MAGNESIUM-7, SODIUM-8, POTASSIUM-9, BICARBONATE-10,      00005940
C     SULFATE-11, CHLORIDE-12, FLOURIDE-13,NITRATE-14,DISSOLVED SOLIDS-100005950
C     HARDNESS-16, IRON-17, MANGANESE-18.                                 00005960
C     THE CHEMICAL DATA ARE ENTERED AS FOLLOWS- Q IN COLS 1-5 RIGHT       00005970
C     JUSTIFIED. THIS MUST BE INSTANTANEOUS DISCHARGE. TEMP IN COLS 6-9,00005980
C     USE DECIMAL PT AND ONE PLACE TO THE RIGHT OF IT. CONDUCTANCE IN CO00005990
C     10-13, RIGHT JUSTIFIED (RJ), PH IN COLS 14-17, WITH A DEC PT & ONE00006000
C     PLACE TO THE RIGHT OF IT. SI IN COLS 18-21, DEC PT & ONE PLACE TO 00006010
C     THE RIGHT. CA IN COLS 22-25 RJ, MAGNESIUM IN COLS 26-28 RJ. NA IN 00006020
C     COLS 29-32 RJ. K IN COLS 33-36 RJ. BICARBONATE IN COLS 37-40 RJ.  00006030
C     SULFATE IN COLS 41-44 RJ. CL IN COLS 45-48 RJ. F IN COLS 49-51,DEC00006040
C     PT & ONE PLACE AFTER. NO3 IN COLS 52-56, DEC PT AND ONE PLACE AFTE00006050
C     DISSOLVED SOLIDS IN COLS57-60 RJ. HARDNESS IN COLS 61-64 RJ. IRON 00006060
C     GIVEN IN MICROGRAMS/LITER IT SHOULD BE CONVERTED TO MILLIGRAMS/LIT00006070
C     BY DIVIDING BY 1000. IT IS IN COLS 65-69 WITH A DEC PT AND TWO      00006080
C     PLACES AFTER. MANGANESE SHOULD SIMILARLY BE PUT INTO MILLIGRAMS/   00006090
C     LITER AND PUT INTO COLS 70-74 WITH A DEC PT AND AND 2 PLACES AFTER00006100
C     IT. ALL MISSING VALUES ARE ENTERED WITH  A -1.                      00006110
      INTEGER HEAD                                                        00006120
      DIMENSION INDEX(18), PARAM(365,18), PRAM(367), STORE(365), LABEL(100006130
     18), PCT(367), HEAD(20)                                              00006140
      DATA LABEL(1)/'QCFS'/,LABEL(2)/'TEMP'/,LABEL(3)/'COND'/,LABEL(4)/'00006150
     1 PH '/,LABEL(5)/' SI '/,LABEL(6)/' CA '/,LABEL(7)/' MG '/,LABEL(8)00006160
     2/' NA '/,LABEL(9)/'  K '/,LABEL(10)/'HCO3'/,LABEL(11)/' SO4'/,LABE00006170
     3L(12)/' CL '/,LABEL(13)/'  F '/,LABEL(14)/' NO3'/,LABEL(15)/' DS '00006180
     4/,LABEL(16)/'HARD'/,LABEL(17)/' FE '/,LABEL(18)/' MN '/             00006190
C     READS HEADING                                                       00006200
      READ (5,12) HEAD                                                    00006210
C     READS NMCNST, THE NUMBER OF CONSTITUENTS ONE IS GOING TO REQUEST    00006220
C     QUALITY DURATION CURVES FOR. THIS WILL BE IN COLS 1-2 RJ OF THE DA00006230
C     CARD (NO DEC PT)                                                    00006240
      READ (5,13) NMCNST                                                  00006250
C     THIS READS THE CODE NUMBERS OF THE PARAMETERS FOR WHICH DURATION    00006260
C     CURVES ARE DESIRED. EACH CODE NUMBER TAKES 2 COLS RJ, STARTING WIT00006270
C     COLS 1-2, THEN COLS 3-4, ETC. EACH CODE NUMBER IS AN INTEGER WITH 00006280
C     DECIMAL PT.                                                         00006290
      READ (5,14) (INDEX(I),I=1,NMCNST)                                   00006300
C     THIS READS NUMANL THE NUMBER OF ANALYSES IN THE DATA SET. THIS IS 00006310
C     COLS1-3 RJ WITH NO DEC PT ON THE DATA CARD                          00006320
      READ (5,15) NUMANL                                                  00006330
C     THIS READS IN ALL THE CHEMICAL INFORMATION OFF THE DATA CARDS       00006340
      DO 1  I=1,NUMANL                                                    00006350
      READ (5,16) (PARAM(I,J),J=1,18)                                     00006360
1     CONTINUE                                                            00006370
      DO 11  IND=1,NMCNST                                                 00006380
      M=(INDEX(IND))                                                      00006390
C     THIS SECTION EXTRACTS THE MINIMUM AND MAXIMUM VALUES OF THE         00006400
C     PARAMETER AND CONSTRUCTS THE SCALE OF THE FLOW DURATION GRAPH       00006410
      PMAX=0.0                                                            00006420
```

```
      PMIN=10000.0
      DO 2 I=1,NUMANL
      IF(PARAM(I,M).GT.PMAX) PMAX=PARAM(I,M)
      IF((PARAM(I,M).LT.PMIN).AND.(PARAM(I,M).GE.0.0)) PMIN=PARAM(I,M)
 2    CONTINUE
      XO=PMIN
      DX=(PMAX-PMIN)/5.0
C
C     THIS SECTION COMPRESSES THE DATA VALUES , REMOVING MISSING VALUES
      II=0
      DO 3 I=1,NUMANL
      IF(PARAM(I,M).LT.0.0) GO TO 3
      II=II+1
      STORE(II)=PARAM(I,M)
 3    CONTINUE
      IF(II.GT.0) GO TO 4
      WRITE (6,17) LABEL(M)
      GO TO 11
 4    DO 5 I=1,II
      PARAM(I,M)=STORE(I)
 5    CONTINUE
C
C     THIS SECTION CALCULATES % EQUALLED OR EXCEEDED FOR EACH PARAMETER
C     VALUE
      DO 6 I1=1,II
      PCT(I1)=0.0
 6    CONTINUE
      DO 7 I1=1,II
      DO 7 I2=1,II
      IF((PARAM(I2,M)).GE.(PARAM(I1,M))) PCT(I1)=PCT(I1)+100./II
 7    CONTINUE
      DO 8 I=1,II
      PRAM(I)=PARAM(I,M)
 8    CONTINUE
      IF(II.EQ.1) GO TO 10
C
C     THIS SECTION SORTS THE PARAMETER VALUES IN DESCENDING ORDER
      N=II-1
      DO 9 I=1,N
      K=I+1
      DO 9 J=K,II
      IF(PCT(I).GE.PCT(J)) GO TO 9
      HOLD1=PCT(I)
      PCT(I)=PCT(J)
      PCT(J)=HOLD1
      HOLD2=PRAM(I)
      PRAM(I)=PRAM(J)
      PRAM(J)=HOLD2
 9    CONTINUE
 10   CALL DURAT (PRAM,PCT,XO,DX,LABEL(M),II,HEAD)
C     OUTPUTTING A TABLE OF VALUES
      WRITE (6,120) (LABEL(M),J=1,4)
 120  FORMAT ('1',4(5X,A4,7X,'PCT',8X))
      WRITE (6,130) (PRAM(I),PCT(I),I=1,N)
 130  FORMAT (4(F10.3,3X,F7.3,8X),/)
 11   CONTINUE
      STOP
C
 12   FORMAT (20A4)
 13   FORMAT (I2)
 14   FORMAT (18I2)
 15   FORMAT (I3)
 16   FORMAT (F5.0,F4.1,F4.0,2F4.1,F4.0,F3.0,5F4.0,F3.1,F5.1,2F4.0,2F5.2
     1)
 17   FORMAT ('1','NO VALUES OF',A4)
      END
C     DURAT IS A SUBROUTINE THAT OUTPUTS A QUALITY DURATION CURVE
      SUBROUTINE DURAT (PRAM,PCT,XO,DX,LABEL,N,HEAD)
```

```
      INTEGER HEAD
      DIMENSION PRAM(N), PCT(N), PLOT(76,51), HEAD(20), GLAB(6)
      DATA HORIZO,VERT,BLANK,AST,DOT/'-','|',' ','*','.'
     1/
C     WRITING OUT THE HEADING
      WRITE (6,8) HEAD
C     PLOTTING UP THE BASIC GRAPH
      DO 1 I=1,76
      DO 1 J=1,51
      PLOT(I,J)=BLANK
 1    CONTINUE
      DO 2 I=2,50
      PLOT(1,I)=VERT
      PLOT(76,I)=VERT
      PLOT(16,I)=DOT
      PLOT(31,I)=DOT
      PLOT(46,I)=DOT
      PLOT(61,I)=DOT
 2    CONTINUE
      DO 3 I=2,75
      PLOT(I,1)=HORIZO
      PLOT(I,51)=HORIZO
      PLOT(I,11)=DOT
      PLOT(I,21)=DOT
      PLOT(I,31)=DOT
      PLOT(I,41)=DOT
 3    CONTINUE
      DO 4 I=1,N
C     BOTH X, THE PARAMETER AXIS AND Y, THE PCT AXIS ARE ARITHMETIC SCAL
C     THE SCALE ON THE PARAMETER AXIS HAS BEEN DETERMINED  FROM THE
C     RANGE OF THE DATA.
      IX=IFIX((PRAM(I)-XO)*15./DX+.5)+1
      IY=IFIX((100.-PCT(I))/2.+.5)+1
      PLOT(IX,IY)=AST
 4    CONTINUE
C     THIS CREATES THE BOTTOM LABELS
      DO 5 I=1,6
      GLAB(I)=(FLOAT(I-1))*DX+XO
 5    CONTINUE
C     OUTPUTTING THE GRAPH
      DO 6 I=1,51
      IJ=102-2*I
      WRITE (6,9) IJ,(PLOT(J,I),J=1,76)
 6    CONTINUE
      WRITE (6,10) GLAB
      WRITE (6,11)  LABEL
      RETURN
C
 8    FORMAT ('1',20A4,//)
 9    FORMAT (' ',I10,2X,76A1)
 10   FORMAT (' ',T7,6(F10.3,5X))
 11   FORMAT (' ',5X,'PERCENT',/,' ',43X,'CONCENTRATION OF:',A4)
      END
C********** VQUADUR ***********************
C     THIS PROGRAM PLOTS QUALITY DURATION CURVES FOR CHOSEN PARAMETERS
C     APRIL 1976
C     HEAD IS THE HEADING CARD WITH STATION NUMBER AND NAME
C     PARAM IS THE ARRAY THAT STORES THE CHEMICAL DATA
C     STORE IS THE ARRAY THAT COMPRESSES THE DATA SET, ELIMINATING GAPS
C     LABEL IS THE ARRAY OF THE  18 CONSTITUENT NAMES
C     PCT IS THE ARRAY OF THE % EXCEEDED OR EQUALLED FOR EACH CHEMICAL
C     READING
C     INDEX IS THE ARRAY THAT RECORDS THE CODE NUMBERS OF THE CHEMICAL
C     CONSTITUENTS FOR WHICH CURVES ARE DESIRED
C     THE CHEMICAL PARAMETERS AND THEIR CORRESPONDING NUMBERS ARE
C     DISCHARGE-1, TEMPERATURE-2, SPECIFIC CONDUCTANCE-3, PH-4, SILICON-
C     CALCIUM-6, MAGNESIUM-7, SODIUM-8, POTASSIUM-9, BICARBONATE-10,
C     SULFATE-11, CHLORIDE-12, FLOURIDE-13,NITRATE-14,DISSOLVED SOLIDS-1
```

```
C      HARDNESS-16, IRON-17, MANGANESE-18.
C      THE CHEMICAL DATA ARE ENTERED AS FOLLOWS- Q IN COLS 1-5 RIGHT
C      JUSTIFIED. THIS MUST BE INSTANTANEOUS DISCHARGE. TEMP IN COLS 6-9,
C      USE DECIMAL PT AND ONE PLACE TO THE RIGHT OF IT. CONDUCTANCE IN CO
C      10-13, RIGHT JUSTIFIED (RJ), PH IN COLS 14-17, WITH A DEC PT 8 ONE
C      PLACE TO THE RIGHT OF IT. SI IN COLS 18-21, DEC PT 8 ONE PLACE TO
C      THE RIGHT. CA IN COLS 22-25 RJ, MAGNESIUM IN COLS 26-28 RJ. NA IN
C      COLS 29-32 RJ. K IN COLS 33-36 RJ. BICARBONATE IN COLS 37-40 RJ.
C      SULFATE IN COLS 41-44 RJ. CL IN COLS 45-48 RJ. F IN COLS 49-51,DEC
C      PT 8 ONE PLACE AFTER. NO3 IN COLS 52-56, DEC PT AND ONE PLACE AFTE
C      DISSOLVED SOLIDS IN COLS57-60 RJ. HARDNESS IN COLS 61-64 RJ. IRON
C      GIVEN IN MICROGRAMS/LITER IT SHOULD BE CONVERTED TO MILLIGRAMS/LIT
C      BY DIVIDING BY 1000. IT IS IN COLS 65-69 WITH A DEC PT AND TWO
C      PLACES AFTER. MANGANESE SHOULD SIMILARLY BE PUT INTO MILLIGRAMS/
C      LITER AND PUT INTO COLS 70-74 WITH A DEC PT AND AND 2 PLACES AFTER
C      IT. ALL MISSING VALUES ARE ENTERED WITH  A -1.
       INTEGER HEAD
       DIMENSION INDEX(18), PARAM(365,18), PRAM(367), STORE(365), LABEL(1
      18), PCT(367), HEAD(20)
       DATA LABEL(1)/'QCFS'/,LABEL(2)/'TEMP'/,LABEL(3)/'COND'/,LABEL(4)/'
      1 PH '/,LABEL(5)/' SI '/,LABEL(6)/' CA '/,LABEL(7)/' MG '/,LABEL(8)
      2/' NA '/,LABEL(9)/'  K '/,LABEL(10)/'HCO3'/,LABEL(11)/' SO4'/,LABE
      3L(12)/' CL '/,LABEL(13)/'  F '/,LABEL(14)/' NO3'/,LABEL(15)/' DS '
      4/,LABEL(16)/'HARD'/,LABEL(17)/' FE '/,LABEL(18)/' MN '/
C      READS HEADING
       READ (5,12) HEAD
C      READS NMCNST, THE NUMBER OF CONSTITUENTS ONE IS GOING TO REQUEST
C      QUALITY DURATION CURVES FOR. THIS WILL BE IN COLS 1-2 RJ OF THE DA
C      CARD (NO DEC PT)
       READ (5,13) NMCNST
C      THIS READS THE CODE NUMBERS OF THE PARAMETERS FOR WHICH DURATION
C      CURVES ARE DESIRED. EACH CODE NUMBER TAKES 2 COLS RJ, STARTING WIT
C      COLS 1-2, THEN COLS 3-4, ETC. EACH CODE NUMBER IS AN INTEGER WITH
C      DECIMAL PT.
       READ (5,14) (INDEX(I),I=1,NMCNST)
C      THIS READS NUMANL THE NUMBER OF ANALYSES IN THE DATA SET. THIS IS
C      COLS1-3 RJ WITH NO DEC PT ON THE DATA CARD
       READ (5,15) NUMANL
C      THIS READS IN ALL THE CHEMICAL INFORMATION OFF THE DATA CARDS
       DO 1 I=1,NUMANL
       READ (5,16) (PARAM(I,J),J=1,18)
 1     CONTINUE
       DO 11 IND=1,NMCNST
       M=(INDEX(IND))
C      THIS SECTION EXTRACTS THE MINIMUM AND MAXIMUM VALUES OF THE
C      PARAMETER AND CONSTRUCTS THE SCALE OF THE FLOW DURATION GRAPH
       PMAX=0.0
       PMIN=10000.0
       DO 2 I=1,NUMANL
       IF(PARAM(I,M).GT.PMAX) PMAX=PARAM(I,M)
       IF((PARAM(I,M).LT.PMIN).AND.(PARAM(I,M).GE.0.0)) PMIN=PARAM(I,M)
 2     CONTINUE
       XO=PMIN
       DX=(PMAX-PMIN)/5.0
C
C      THIS SECTION COMPRESSES THE DATA VALUES , REMOVING MISSING VALUES
       II=0
       DO 3 I=1,NUMANL
       IF(PARAM(I,M).LT.0.0) GO TO 3
       II=II+1
       STORE(II)=PARAM(I,M)
 3     CONTINUE
       IF(II.GT.0) GO TO 4
       WRITE (6,17) LABEL(M)
       GO TO 11
 4     DO 5 I=1,II
       PARAM(I,M)=STORE(I)
 5     CONTINUE
```

```
C
C     THIS SECTION CALCULATES % EQUALLED OR EXCEEDED FOR EACH PARAMETER
C     VALUE
      DO 6 I1=1,II
      PCT(I1)=0.0
 6    CONTINUE
      DO 7 I1=1,II
      DO 7 I2=1,II
      IF((PARAM(I2,M)).GE.(PARAM(I1,M))) PCT(I1)=PCT(I1)+100./II
 7    CONTINUE
      DO 8 I=1,II
      PRAM(I)=PARAM(I,M)
 8    CONTINUE
      IF(II.EQ.1) GO TO 10
C
C     THIS SECTION SORTS THE PARAMETER VALUES IN DESCENDING ORDER
      N=II-1
      DO 9 I=1,N
      K=I+1
      DO 9 J=K,II
      IF(PCT(I).GE.PCT(J)) GO TO 9
      HOLD1=PCT(I)
      PCT(I)=PCT(J)
      PCT(J)=HOLD1
      HOLD2=PRAM(I)
      PRAM(I)=PRAM(J)
      PRAM(J)=HOLD2
 9    CONTINUE
 10   CONTINUE
      CALL DURATV(PRAM,PCT,LABEL(M),II,HEAD)
C     OUTPUTTING A TABLE OF VALUES
      WRITE (6,120) (LABEL(M),J=1,4)
 120  FORMAT ('1',4(4X,A4,6X,'PCT',8X))
      WRITE (6,130) (PRAM(I),PCT(I),I=1,N)
 130  FORMAT (4(F10.3,3X,F7.3,5X),/)
 11   CONTINUE
      STOP
C
 12   FORMAT (20A4)
 13   FORMAT (I2)
 14   FORMAT (18I2)
 15   FORMAT (I3)
 16   FORMAT (F5.0,F4.1,F4.0,2F4.1,F4.0,F3.0,5F4.0,F3.1,F5.1,2F4.0,2F5.2
     1)
 17   FORMAT ('1','NO VALUES OF',A4)
      END
C     DURATV IS A SUBROUTINE THAT OUTPUTS A QUALITY DURATION CURVE
C      ON THE VERSATEC PLOTTER.
      SUBROUTINE DURATV (PRAM,PCT,LABEL,N,HEAD)
      DIMENSION JLABEL(6)
      INTEGER HEAD
      DIMENSION PRAM(367), PCT(367),  HEAD(20)
      EQUIVALENCE(JLABEL(6),ILABEL)
      DATA JLABEL/'CONC','ENTR','ATIO','N OF',' :  ','    '/
      ILABEL=LABEL
      DATA LMASK/Z3333/
      CALL WINDOW(-0.5,7.5,-0.5,9.5)
      CALL PLOTS(0,0,0)
C  PLOT HEADING.
      CALL SYMBOL(0.1,9.0,0.10,HEAD,0.,80)
C  PLOT X AXIS.
      CALL SCALE(PRAM,7.0,N,1)
      CALL AXIS(0.0,0.0,JLABEL,-24,7.0,0.,PRAM(N+1),PRAM(N+2))
C  PLOT Y AXIS.
      CALL SCALE(PCT,8.0,N,1)
      PCT(N+2)=12.5
      CALL AXIS(0.0,0.0,'PERCENT',7,8.0,90.,PCT(N+1),PCT(N+2))
C  PLOT GRID.
```

```
      CALL GRID(0.0,0.0,7,1.0,8,1.0,LMASK)
C  PLOT DATA
      CALL NEWPEN(5)
      CALL LINE(PRAM,PCT,N,1,0)
C  END PLOT
      CALL PLOT(0.,0.,999)
      RETURN
C
      END
C********** FLOWDUR ***********************
C     THIS PROGRAM PRINTS OUT BOTH DISCHARGE AND NORMALIZED DISCHARGE FL
C     DURATION CURVES FOR ONE YEAR OF DISCHARGE RECORDS
C     MISSING VALUES ARE ENTERED AS A -1
C     HEAD IS THE STATION NUMBER AND TITLE
C     DRA IS THE DRAINAGE AREA
C     Q IS THE ARRAY OF THE DAILY DISCHARGE VALUES
C     PCT IS THE ARRAY OF THE % EXCEEDED OR EQUALLED FOR EACH DISCHARGE
C     HOLD IS AN ARRAY THAT COMPRESSES THE DISCHARGE VALUES, REMOVING GA
C     IN THE RECORD
C     N= # OF DAYS IN YEAR
      DIMENSION HEAD(16), Q(365), HOLD(365), PCT(365)
      DATA PCT/365*0.0/
C     READ IN TITLE AND DRAINAGE AREA :
      READ (5,6) HEAD,DRA,N
      IF(N.NE.365) GO TO 7
C     READ IN DISCHARGE VALUES,CHRONOLOGICALLY
      READ (5,8)  Q
      NEWN=0
      DMAX=0.0
      DO 1 I=1,365
C     TEST FOR MISSING VALUES:
      IF(Q(I).LE.0.0) GO TO 1
      NEWN=NEWN+1
      HOLD(NEWN)=Q(I)
      IF(Q(I).GT.DMAX)DMAX=Q(I)
 1    CONTINUE
      IF(DMAX/DRA.GT.100.0) GO TO 9
      DO 2 I=1,NEWN
C     RELOAD DISCHARGE ARRAY WITH GAPS REMOVED
      Q(I)=HOLD(I)
 2    CONTINUE
C
C     CALCULATE % EQUALLED OR EXCEEDED FOR EACH DISCHARGE VALUE:
      DO 3 I=1,NEWN
      DO 3 J=1,NEWN
      IF(Q(J).GE.Q(I)) PCT(I)=PCT(I)+100./NEWN
 3    CONTINUE
C
C     SORT DIS VALUES INTO ASCENDING ORDER, PCT VALUES INTO DESCENDING.
      NI=NEWN-1
      DO 4 I=1,NI
      K=I+1
      DO 4 J=K,NEWN
      IF(PCT(I).GE.PCT(J)) GO TO 4
      HOLD1=PCT(I)
      PCT(I)=PCT(J)
      PCT(J)=HOLD1
      HOLD2=Q(I)
      Q(I)=Q(J)
      Q(J)=HOLD2
 4    CONTINUE
      CALL FLDR (Q,PCT,NEWN,HEAD,DRA)
C
C     CONVERT DISCHARGE INTO NORMALIZED DISCHARGE
      DO 5 I=1,NEWN
      Q(I)=Q(I)/DRA
 5    CONTINUE
      CALL FLODUR (Q,PCT,NEWN,HEAD,DRA)
```

```
      STOP
 7    WRITE(6,60) N
 60   FORMAT('0','***** ERROR *****  N IS ',I3,'.  THIS PROGRAM IS DESIG
     *NED FOR WATER YEARS OF 365 DAYS'/'0',' BEGINNING IN OCTOBER.  PLEA
     *SE USE ANOTHER PROGRAM FOR OTHER TYPES OF RECORDS.')
      STOP
C
 9    WRITE(6,80)DMAX,DRA
 80   FORMAT('0','***** ERROR *****  MAXIMUM DISCHARGE IS ',F10.0,'. DRA
     *INAGE AREA IS ',F8.2,'.  '/'0','          THE RATIO DISCHARGE/DRA
     *INAGE AREA EXCEEDS 100 CFS/SQ.MI.')
      STOP
 6    FORMAT (16A4,2X,F8.0,3X,I3)
 8    FORMAT (10F8.0)
      END
C     FLDR IS A SUBROUTINE THAT PRINTS THE FLOW DURATION CURVE
C     OF THE DISCHARGE
      SUBROUTINE FLDR (Q,PCT,N,HEAD,DRA)
      DIMENSION Q(N), PCT(N), HEAD(16), PLOT(76,51), LABEL(6)
      REAL LABEL
      DATA HORIZO,VERT,BLANK,AST,DOT/'-','|',' ','*','.'
     1/
C
C     KOUNT KEEPS TRACK OF THE # OF PTS OFF THE GRAPH
      KOUNT=0
      WRITE (6,10) HEAD,DRA
C
C     CREATES BASIC GRAPH OUTLINE:
      DO 1 I=1,76
      DO 1 J=1,51
      PLOT(I,J)=BLANK
 1    CONTINUE
      DO 2 I=2,50
      PLOT(1,I)=VERT
      PLOT(76,I)=VERT
      PLOT(16,I)=DOT
      PLOT(31,I)=DOT
      PLOT(46,I)=DOT
      PLOT(61,I)=DOT
 2    CONTINUE
      DO 3 I=2,75
      PLOT(I,1)=HORIZO
      PLOT(I,51)=HORIZO
      PLOT(I,11)=DOT
      PLOT(I,21)=DOT
      PLOT(I,31)=DOT
      PLOT(I,41)=DOT
 3    CONTINUE
C
C     THIS SECTION ASSIGNS PTS ON GRAPH FOR DISCHARGE,PCT VALUES
      MIN=0
      DO 4 I=1,N
      IEDG=IFIX(ALOG10(Q(I)))-1
      IF(IEDG.LT.MIN) MIN=IEDG
 4    CONTINUE
      DO 7 I=1,N
C     CANNOT TAKE LOG OF 0
      IF(Q(I).LE.0.0) GO TO 5
C     15 SPACES=1 LOG CYCLE
      IX=IFIX((ALOG10(Q(I))-MIN)*15.+.5)+1
C     PCT IS A SIMPLE ARITHMETIC SCALE
      IY=IFIX((100.-PCT(I))/2.+.5)+1
      IF((IX.LE.76).AND.(IX.GE.1)) GO TO 6
 5    KOUNT=KOUNT+1
      GO TO 7
 6    PLOT(IX,IY)=AST
 7    CONTINUE
C
```

```
C     WRITES OUT GRAPH
      DO 8 I=1,51
      IJ=102-2*I
      WRITE (6,11) IJ,(PLOT(J,I),J=1,76)
 8    CONTINUE
C     APPROPRIATE LABELS:
      DO 9 I=1,6
      LABEL(I)=10.**((MIN-1)+I)
 9    CONTINUE
      WRITE (6,12) LABEL
      WRITE (6,13)
      WRITE (6,14) KOUNT
C
C     WRITING A TABLE OF VALUES:
      WRITE (6,15)
      WRITE (6,16) (Q(I),PCT(I),I=1,N)
      RETURN
C
 10   FORMAT ('1',16A4,1X,F7.1,'SQMI',//)
 11   FORMAT (' ',I10,2X,76A1)
 12   FORMAT (' ',T5,6(F10.3,5X))
 13   FORMAT (' ',5X,'PERCENT',/,' ',43X,'Q, IN CFS')
 14   FORMAT ('0','# OF PTS OFF GRAPH=',I3)
 15   FORMAT ('1',6(5X,'Q CFS',7X,'PCT'))
 16   FORMAT (12F10.2)
      END
C     FLODUR IS A SUBROUTINE THAT PRINTS THE FLOW DURATION CURVE FOR
C     NORMALIZED DISCHARGE
      SUBROUTINE FLODUR (Q,PCT,N,HEAD,DRA)
      DIMENSION Q(N), PCT(N), HEAD(16), PLOT(76,51), LABEL(6)
      REAL LABEL
      DATA HORIZO,VERT,BLANK,AST,DOT/'-','|',' ','*','.'
     1/
C
C     KOUNT KEEPS TRACK OF THE # OF PTS OFF THE GRAPH
      KOUNT=0
      WRITE (6,10) HEAD,DRA
C
C     CREATES BASIC GRAPH OUTLINE:
      DO 1 I=1,76
      DO 1 J=1,51
      PLOT(I,J)=BLANK
 1    CONTINUE
      DO 2 I=2,50
      PLOT(1,I)=VERT
      PLOT(76,I)=VERT
      PLOT(16,I)=DOT
      PLOT(31,I)=DOT
      PLOT(46,I)=DOT
      PLOT(61,I)=DOT
 2    CONTINUE
      DO 3 I=2,75
      PLOT(I,1)=HORIZO
      PLOT(I,51)=HORIZO
      PLOT(I,11)=DOT
      PLOT(I,21)=DOT
      PLOT(I,31)=DOT
      PLOT(I,41)=DOT
 3    CONTINUE
C
C     THIS SECTION ASSIGNS PTS ON GRAPH FOR DISCHARGE,PCT VALUES
      MIN=0
      DO 4 I=1,N
      IEDG=IFIX(ALOG10(Q(I)))-1
      IF(IEDG.LT.MIN) MIN=IEDG
 4    CONTINUE
      DO 7 I=1,N
C     CANNOT TAKE LOG OF 0
```

```
      IF(Q(I).LE.0.0) GO TO 5
C     15 SPACES=1 LOG CYCLE
      IX=IFIX((ALOG10(Q(I))-MIN)*15.+.5)+1
C     PCT IS A SIMPLE ARITHMETIC SCALE
      IY=IFIX((100.-PCT(I))/2.+.5)+1
      IF((IX.LE.76).AND.(IX.GE.1)) GO TO 6
 5    KOUNT=KOUNT+1
      GO TO 7
 6    PLOT(IX,IY)=AST
 7    CONTINUE
C
C     WRITES OUT GRAPH
      DO 8 I=1,51
      IJ=102-2*I
      WRITE (6,11) IJ,(PLOT(J,I),J=1,76)
 8    CONTINUE
C     APPROPRIATE LABELS:
      DO 9 I=1,6
      LABEL(I)=10.**((MIN-1)+I)
 9    CONTINUE
      WRITE (6,12) LABEL
      WRITE (6,13)
      WRITE (6,14) KOUNT
C
C     WRITING A TABLE OF VALUES:
      WRITE (6,15)
      WRITE (6,16) (Q(I),PCT(I),I=1,N)
      RETURN
C
 10   FORMAT ('1',16A4,1X,F7.1,'SQMI',//)
 11   FORMAT (' ',I10,2X,76A1)
 12   FORMAT (' ',T5,6(F10.3,5X))
 13   FORMAT (' ',5X,'PERCENT',/,' ',43X,'Q, IN CFS/SQ MI. DRAINAGE AREA
     1')
 14   FORMAT ('0','# OF PTS OFF GRAPH=',I3)
 15   FORMAT ('1',6(3X,'Q-CFS/SQMI',4X,'PCT'))
 16   FORMAT (12F10.2)
      END
C********** VFLOWDUR ***********************
C     THIS PROGRAM UTILIZES VARIOUS FLOW SEPARATION TECHNIQUES TO
C     DETERMINE THE RELATIVE CONTRIBUTIONS OF GROUND WATER RUNOFF AND
C     SURFACE RUNOFF TO STREAM FLOW
C
      DIMENSION STA(16), DIS(1095), GDIS(1095)
      NOOLD=0
      NCNT=0
C     READS THE STATION NAME AND NUMBER AND THE AREA OF THE BASIN
 1    READ (5,3,END=2)IYR, NO,STA,DRA,N
C
      IF(NO.NE.NOOLD.AND.NCNT.GT.0) CALL PLOTE2
      IF(NO.NE.NOOLD) NCNT=1
      IF(NO.EQ.NOOLD) NCNT=NCNT+1
C
C     READS IN DISCHARGE VALUES FROM CARDS
      READ (5,4,END=2) (DIS(I),I=1,N)
C
C     THE SUBROUTINES ARE EACH SUMMONED BY A DIFFERENT CALL STATEMENT:
C              INSERT AFTER THIS
C     *****************************************************************
      CALL VFLWDA (STA,DRA,DIS,N,NCNT)
C     *******************************************************************
C              SUBROUTINES BEFORE THIS
      NOOLD=NO
      GO TO 1
 2    CALL PLOTE2
      STOP
C
C
```

```
 3    FORMAT ( I2,I8,T1,16A4,2X,F8.0,3X,I3)
 4    FORMAT ( 10(F8.0))
      END
      SUBROUTINE NDTRI (P,X,D,IE)
C        SEE FORTRAN SSP FOR COMPLETE WRITEUP...
      IE=0
      X=.99999E+74
      D=X
      IF(P) 1,3,2
 1    IE=-1
      GO TO 10
 2    IF(P-1.0) 5,4,1
 3    X=-.99999E+74
 4    D=0.0
      GO TO 10
 5    D=P
      IF(D-0.5) 7,7,6
 6    D=1.0-D
 7    T2=ALOG(1.0/(D*D))
      T=SQRT(T2)
      X=T-(2.515517+0.802853*T+0.010328*T2)/(1.0+1.432788*T+0.189269*T2+
     10.001308*T2)
      IF(P-0.5) 8,8,9
 8    X=-X
 9    D=0.3989423*EXP(-X*X/2.0)
 10   RETURN
      END
      SUBROUTINE VFLWDA (STA,DRA,DIS,N,NCNT)
C        THIS SUBROUTINE CALCULATES A FLOW DURATION CURVE FOR
C        THE YEAR AND PRINTS IT OUT ON THE VERSATEC PLOTTER.
C        ON LOGRITHMIC-PROBABILITY PAPER...
      DIMENSION STA(16), DISDEN(1095), INDX(1095), APER(1095), DIS(1095)
      DIMENSION AY(46), AX(23), DDS(1095)
      DATA AX/.001,.002,.005,.01,.02,.05,.1,.2,.25,.30,.40,.50,.60,.70,.
     175,.80,.90,.95,.98,.99,.995,.998,.999/
      DATA AY/.001,.002,.003,.004,.005,.006,.007,.008,.009,.01,.02,.03,.
     104,.05,.06,.07,.08,.09,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.,2.,3.,4.,5.,6
     2.,7.,8.,9.,10.,20.,30.,40.,50.,60.,70.,80.,90.,100./
      RNCNT=FLOAT(NCNT)
C        THIS SECTION CREATES THE BASIC GRAPH OUTLINE...
      IF(NCNT.GT.1) GO TO 9
      CALL PLOT (1.0,1.0,-3)
      CALL SYMBOL (0.0,-1.0,0.14,'PERCENT OF TIME DISCHARGE IS EQUALLED
     1OR EXCEEDED',0.0,49)
      CALL SYMBOL (-1.0,1.0,0.14,'DISCHARGE IN CFS/MI 2',90.0,21)
      DO 5 I=1,46
      YPLOT=(ALOG10(AY(I))*2.25)+6.75
      IF(AY(I).LT.0.01) GO TO 1
      IF(AY(I).LT.0.10) GO TO 2
      IF(AY(I).LT.1.00) GO TO 3
      CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,-1)
      GO TO 4
 1    CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,3)
      GO TO 4
 2    CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,2)
      GO TO 4
 3    CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,1)
 4    CALL PLOT (0.3,YPLOT,3)
      CALL PLOT (9.6,YPLOT,2)
 5    CONTINUE
      DO 8 I=1,23
      CALL NDTRI (AX(I),X,D,IER)
      XPLOT=5.0+X*1.5
      IF(AX(I).LT.0.1.OR.AX(I).GT.0.99) GO TO 6
      CALL NUMBER ((XPLOT-0.07),-0.4,0.07,(100.*AX(I)),0.0,-1)
      GO TO 7
 6    CALL NUMBER ((XPLOT-0.07),-0.4,0.07,(100.*AX(I)),0.0,1)
 7    CALL PLOT (XPLOT,0.0,3)
```

```
      CALL PLOT (XPLOT,11.3,2)
 8    CONTINUE
 9    NMISS=0
      NOFLOW=0
      MMM=0
      NNM=0
C         DATA SCAN FOR POSSIBLE MISSING DATA OR NO FLOW (<0.01)
      DO 11 I=1,N
      IF(DIS(I).LT.0.0) GO TO 10
      IF(DIS(I).LT.0.01) NOFLOW=NOFLOW+1
      NNM=NNM+1
      DDS(NNM)=DIS(I)
      GO TO 11
10    NMISS=NMISS+1
11    CONTINUE
      MMM=MMM+NNM
      M=NNM-1
      DO 13 I=1,M
      L=NNM-1
      DO 12 J=1,L
      IF(DDS(J).LE.DDS(J+1)) GO TO 12
      XR=DDS(J)
      DDS(J)=DDS(J+1)
      DDS(J+1)=XR
12    CONTINUE
13    CONTINUE
      DAYS=FLOAT(NNM)
      DO 14 I=1,NNM
      APER(I)=(NNM-I+1.)*100/NNM
      DISDEN(I)=DDS(I)/DRA
14    CONTINUE
C         WRITES OUT FLOW DURATION TABLE
      WRITE (6,34) STA,DRA
      DO 15 I=1,NNM,8
      IF(NNM.EQ.365.AND.I.EQ.361) GO TO 16
      II=I+7
      WRITE (6,36) (APER(N),DISDEN(N),N=I,II)
15    CONTINUE
      GO TO 20
16    WRITE (6,37) (APER(N),DISDEN(N),N=361,365)
      DELTA1=DISDEN(37)-DISDEN(36)
      DELTA2=DISDEN(329)-DISDEN(328)
      DELTA3=DISDEN(92)-DISDEN(91)
      DELTA4=DISDEN(274)-DISDEN(273)
      Q90=DISDEN(36)+(DELTA1/2)
      Q10=DISDEN(328)+(DELTA2/2)
      Q75=DISDEN(91)+(DELTA3/4)
      Q25=DISDEN(274)-(DELTA4/4)
      IF(Q90.LE.0.) GO TO 17
      IF(Q75.LE.0.) GO TO 18
      GO TO 19
17    WRITE (6,39)
      IF(Q90.LE.0.) Q90=0.001
      IF(Q75.NE.0.0) GO TO 19
18    WRITE (6,40)
      IF(Q75.LE.0.) Q75=0.001
      GO TO 19
19    RT1090=SQRT(Q10/Q90)
      RT2575=SQRT(Q25/Q75)
      WRITE (6,38) RT1090,RT2575
20    CONTINUE
C     GRAPHS CURVES ON LOG-PROBABILITY SCALE
      INDEX1=NNM/3
      INDEX2=INDEX1*2
      DO 21 I=1,NNM
      DAS=DDS(I)/DRA
      IF(DAS.LT.0.001) DAS=0.001
      YY=(ALOG10(DAS)*2.25)+6.75
```

```
      IC=2
      IF(I.EQ.1) IC=3
      XPER=APER(I)/100.
      IF(XPER.GE.1.0) XPER=.999
      IF(XPER.LE.0.001) XPER=.001
      CALL NDTRI (XPER,X,D,IER)
      IF(IER.NE.0) WRITE (6,35)
      XX=5.0+X*1.5
      IF(I.EQ.1) CALL NUMBER ((XX+0.02),YY,0.07,RNCNT,0.0,-1)
      CALL PLOT (XX,YY,IC)
      IF(I.EQ.INDEX1.AND.NCNT.EQ.1) CALL SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(I.EQ.INDEX2.AND.NCNT.EQ.1) CALL SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(I.EQ.INDEX1.AND.NCNT.EQ.2) CALL SYMBOL (XX,YY,0.035,2,0.0,-1)
      IF(I.EQ.INDEX2.AND.NCNT.EQ.2) CALL SYMBOL (XX,YY,0.035,2,0.0,-1)
      IF(I.EQ.INDEX1.AND.NCNT.EQ.3) CALL SYMBOL (XX,YY,0.035,3,0.0,-1)
      IF(I.EQ.INDEX2.AND.NCNT.EQ.3) CALL SYMBOL (XX,YY,0.035,3,0.0,-1)
      IF(XPER.GT.0.95.AND.NCNT.EQ.1.OR.XPER.LT.0.05.AND.NCNT.EQ.1) CALL
     1SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(XPER.GT.0.95.AND.NCNT.EQ.2.OR.XPER.LT.0.05.AND.NCNT.EQ.2) CALL
     1SYMBOL (XX,YY,0.035,2,0.0,-1)
      IF(XPER.GT.0.95.AND.NCNT.EQ.3.OR.XPER.LT.0.05.AND.NCNT.EQ.3) CALL
     1SYMBOL (XX,YY,0.035,3,0.0,-1)
   21 CONTINUE
      IF(NCNT.GT.0) CALL NUMBER ((XX-0.07),YY,0.07,RNCNT,0.0,-1)
      IF(NOFLOW.GT.0) GO TO 22
      GO TO 25
C     INDICATES POSITION OF LAST NO FLOW WITH AN ASTERISK(IF NOFLOW>0)
   22 DO 24 I=1,NNM
      IF(DDS(I).GT.0.01) GO TO 24
      IF(DDS(I).LT.0.01.AND.DDS(I+1).GT.0.01) GO TO 23
      GO TO 24
   23 XPER=APER(I)/100.
      IF(XPER.LE.0.001) XPER=.001
      CALL NDTRI (XPER,X,D,IER)
      XX=5.0+X*1.5
      CALL SYMBOL (XX,-0.10,0.14,11,0.0,-1)
   24 CONTINUE
C         WRITES SUMMARY INFORMATION AT TOP OF PAGE FOR EACH CURVE
   25 IF(NCNT-2) 26,27,28
   26 CALL NUMBER (0.5,13.25,0.14,RNCNT,0.0,-1)
      CALL SYMBOL (1.0,13.25,0.14,STA,0.0,64)
      XPL=0.0
      GO TO 29
   27 CALL NUMBER (0.5,13.0,0.14,RNCNT,0.0,-1)
      CALL SYMBOL (1.0,13.,0.14,STA,0.0,64)
      XPL=3.3
      GO TO 29
   28 CALL NUMBER (0.5,12.75,0.14,RNCNT,0.0,-1)
      CALL SYMBOL (1.0,12.75,0.14,STA,0.0,64)
      XPL=6.6
   29 CALL NUMBER ((XPL+0.5),12.5,0.14,RNCNT,0.0,-1)
      CALL NUMBER (XPL,12.25,0.07,DAYS,0.0,-1)
      CALL SYMBOL ((XPL+0.28),12.25,0.07,'DAYS PLOTTED',0.0,12)
      IF(NMISS.GT.0) GO TO 30
      IF(NOFLOW.GT.0) GO TO 31
      GO TO 32
   30 RMISS=FLOAT(NMISS)
      CALL NUMBER (XPL,12.0,0.07,RMISS,0.0,-1)
      CALL SYMBOL ((XPL+0.28),12.0,0.07,' DAYS MISSING DATA',0.0,18)
      IF(NOFLOW.EQ.0) GO TO 32
   31 ROFLOW=FLOAT(NOFLOW)
      CALL NUMBER (XPL,11.75,0.07,ROFLOW,0.0,-1)
      CALL SYMBOL ((XPL+0.28),11.75,0.07,' DAYS NO FLOW(*)',0.0,16)
   32 IF(NNM.NE.365) GO TO 33
      CALL SYMBOL (XPL,11.5,0.07,'(Q 10 /Q 90 ) 1/2 =',0.0,19)
      CALL NUMBER ((XPL+1.75),11.5,0.07,RT1090,0.0,2)
      CALL SYMBOL (XPL,11.30,0.07,'(Q 25 /Q 75 ) 1/2 =',0.0,19)
      CALL NUMBER ((XPL+1.75),11.30,0.07,RT2575,0.0,2)
```

```
 33    RETURN
C
 34    FORMAT ('1','FLOW-DURATION CURVE FOR',17X,16A4,2X,F8.2,2X,'SQ.MI')
 35    FORMAT ('0',' * * * * * * * * * * * W A R N I N G  ERROR IN NDTRI')
 36    FORMAT (' ',4X,8(F6.2,1X,F6.3,3X))
 37    FORMAT (' ',4X,5(F6.2,1X,F6.3,3X))
 38    FORMAT ('0',7X,'THE RATIO (Q10/Q90)**1/2 =',F8.2,10X,'(Q25/Q75)**1
      1/2 =',F8.2)
 39    FORMAT (' ',' Q90 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANINGL
      1ESS.')
 40    FORMAT (' ','   Q75 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANIN
      1GLESS.')
       END
C********** FLOW ************************
C    HYDROCRAPH FLOW SEPARATION PROGRAM
C
C       MODIFED BY R. DIXON FROM PROGRAMS WRITTEN BY R.J. HENNING
C         AND T. CROLL     ( 77.09.22 )
C       PROBLEMS WITH THIS PROGRAM SHOULD BE DIRECTED TO:
C                ROGER J. HENNING
C            C/O DR. WAYNE A. PETTYJOHN
C                DEPARTMENT OF GEOLOGY AND MINERALOGY
C                125 S. OVAL MALL
C                THE OHIO STATE UNIVERSITY
C                COLUMBUS, OHIO   43210
C
C    *************************************************************
C            OSU IRCC FORTRAN (G1) COMPILER
C                  SUBROUTINE REREAD IS COMPILED IN IBM 370/VM
C                    ASSEMBLER LANGUAGE .  THIS PROGRAM CAN BE
C                    SUPPLIED IN A VERSION THAT DOES NOT REQUIRE
C                    REREAD CAPABILITIES.  FORTRAN 'REWIND' CAN BE
C                    SUBSTITUTED, BUT IS IS NOT COST EFFICIENT.
C
C       INPUT TO THIS PROGRAM CONSISTS OF CONTROL CARDS WRITTEN
C       IN A "COMMAND LANGUAGE" AND DISCHARGE AND STATION DATA.
C
C       THIS PROGRAM IS DESIGNED TO READ IN DISCHARGE DATA FROM CARDS
C       AND DO VARIOUS CALCULATIONS WITH A VARIETY OF OUTPUT MODES.
C       THE COMMAND LANGUAGE CONSISTS OF ENGLISH LANUAGE COMMANDS
C       THAT DETERMINE THE OPTIONS TO BE USED AND CAUSES THE
C       APPROPRIATE BRANCHING.
C       THE IMPORTANT SECTION OF THE CONTROL "COMMAND LANGUAGE CARDS"
C       IS CARD COLUMNS 22 THROUGH 26.  IF THE CONTROL CARDS DO NOT
C       CONTAIN THE EXPECTED LETTER-NUMBER COMBINATIONS IN THESE
C       COLUMNS, THE PROGRAM WILL FLUSH TO THE NEXT READ COMMAND.
C       THE CONTROL CARD OPTIONS AND THE FUNCTION THEY PERFORM ARE:
C
C    CC  123456789...............................
C    -------------------------------------------------------------
C    /
C    |
C    |      INPUT COMMAND CARD
C    |
C    |READ DISCHARGE DATA FROM CARDS(10 TO A CARD,8 COLUMNS EACH.)
C    |
C    |
C    |      CALCULATION COMMAND CARDS
C    |
C    |AND CALCULATE BY THE FIXED INTERVAL METHOD
C    |AND CALCULATE BY THE SLIDING INTERVAL METHOD
C    |AND CALCULATE BY THE LOCAL MINIMA METHOD
C    |
C    |      OUTPUT COMMAND CARDS
C    |
C    |AND PRINT OUT SUMMARY STATISTICS FOR THE YEAR
C    |AND PRINT OUT MONTH-BY-MONTH STATISTICS
C    |AND PRINT OUT A HYDROGRAPH ON THE LINE PRINTER
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C      IAND PUNCH CARDS TO BE USED AS INPUT TO THE CALCOMP PLOT PROGRAM
C      IAND ON VERSATEC PLOT A HYDROGRAPH WITH SEPARATION
C      IAND PRINT OUT A FLOW DURATION CURVE ON THE LINE PRINTER
C      IAND ON THE VERSATEC PLOT A FLOW DURATION CURVE
C      I
C      I     SAMPLE DATA CARDS
C      I
C      I     TITLE CARD (YR. IN CC 1-2,STA. NO. IN CC 3-10, LITERAL
C      I       TITLE IN CC 11-66, DRAINAGE AREA IN CC 67-74 (WITH
C      I       DECIMAL POINT), AND 365 IN CC 78-80)
C      I
C      I6303123456 OHIO STREAM AT AMERICUS, OH.                123.4    36
C      I
C      I     DISCHARGE DATA CARDS (37 CARDS PER STATION PER YEAR,
C      I       WITH 10 DAYS PER CARD, EACH PUNCHED IN A 8 COLUMN FIELD,
C      I       EITHER WITH A DECIMAL POINT OR RIGHT JUSTIFIED.)
C      I
C      I     1.2      1.9      9.5      235      2580     5678     785.    ...
C      I
C
C      $$**** THE PROPER SEQUENCE OF CARDS SHOULD BE:
C
C      A  *JCL PROGRAM CONTROL CARDS (DEPENDING ON THE COMPUTER INSTALLAT
C      B   *INPUT COMMAND CARD
C      C   *STATION TILE CARD
C      D   *37 DISCHARGE DATA CARDS
C      E   *CALCULATION COMMAND CARD (ONE ONLY, FOLLOWED BY FROM ONE TO
C            SEVEN OUTPUT COMMAND CARDS.)
C      F   *OUTPUT COMMAND CARD(S)  (AT LEAST ONE)
C
C         REPEAT E AND F FOR AS MANY DIFFERENT CALCULATION TECHNIQUES
C            AS DESIRED.
C      ** SPECIAL NOTE *** FLOW DURATION OUTPUT COMMAND CARD(S) MUST
C            ALWAYS BE THE LAST ROUTINES CALLED FOR ANY STATION (IF
C            DESIRED FOR THAT STATION.)
C
C         SEQUENCE OF B THROUGH F CAN BE REPEATED FOR AS MANY
C         STATIONS AS DESIRED.
C
C      ******************************************************************
      DIMENSION DIS(365)
      LOGICAL FLUSH/.FALSE./
      INTEGER*4 CDTYPE(11),TYPE,CARD(20),READ/'READ'/
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA CDTYPE/'ROM ','FIXE','SLID','LOCA','MMAR','Y-MO','GRAP','A HY
     1','A FL','DURA',' USE'/
      NN=0
C     CARD-TYPE SYSTEM TO RECOGNIZE INPUT CARDS AND BRANCH ACCORDINGLY.
      CALL REREAD
    1 CONTINUE
      READ (5,21,END=19) CARD
      WRITE (6,22) CARD
      READ (99,23) TYPE
      DO 2 I=1,11
      IF(CDTYPE(I).EQ.TYPE) GO TO 3
    2 CONTINUE
      WRITE (6,24)
      FLUSH=.TRUE.
      GO TO 1
    3 CONTINUE
      IF((FLUSH).AND.(CARD(1).NE.READ)) GO TO 1
      GO TO (4,5,6,7,8,9,10,11,12,13,14), I
C
    4 CONTINUE
C     READ DISCHARGE DATA FROM CARDS(10 TO A CARD, 8 COLUMNS EACH.)
      FLUSH=.FALSE.
      CALL NORERD
      GO TO 15
```

```
C
 5      CONTINUE
C       AND CALCULATE BY THE FIXED INTERVAL METHOD.
        CALL FXINTR
        GO TO 1
C
 6      CONTINUE
C       AND CALCULATE BY THE SLIDING INTERVAL METHOD
        CALL SLINTR
        GO TO 1
C
 7      CONTINUE
C       AND CALCULATE BY THE LOCAL MINIMA METHOD
        CALL LOCMIN
        GO TO 1
C
 8      CONTINUE
C       AND PRINT OUT SOME SUMMARY STATISTICS FOR THE YEAR
        CALL STATGW
        GO TO 1
C
 9      CONTINUE
C       AND PRINT OUT MONTH-BY-MONTH SUMMARY STATISTICS
        CALL MONTHS
        GO TO 1
C
 10     CONTINUE
C       AND PRINT OUT A HYDROGRAPH ON THE LINE PRINTER
        CALL HYDGRH
        GO TO 1
C
 11     CONTINUE
C       AND ON VERSATEC PLOT A HYDROGRAPH WITH SEPARATION
        CALL VERSAP
        GO TO 1
C
 12     CONTINUE
C       AND ON VERSATEC PLOT A FLOW DURATION CURVE
        CALL VFLWDA
        GO TO 1
C
 13     CONTINUE
C       AND PRINT OUT A FLOW DURATION CURVE ON THE LINE PRINTER
        CALL FLWDUR
        GO TO 1
C
 14     CONTINUE
C       AND PUNCH CARDS TO BE USED AS INPUT TO THE CALCOMP PLOT PROGRAM
        CALL PUNCHR
        GO TO 1
C
C
 15     READ (5,25) STA,DRA,N
        WRITE (6,29)
        WRITE (6,30) STA,DRA,N
        WRITE (6,29)
        READ (5,26) DIS
        IF(N.NE.365) GO TO 17
        NN=NN+1
        DMAX=0.0
        NMISS=0
        DO 16 I=1,365
        IF(DMAX.LT.DIS(I)) DMAX=DIS(I)
        IF(DIS(I).LT.0.0) NMISS=NMISS+1
        DSS(I)=DIS(I)
        IF(DIS(I).LT.0.0) DSS(I)=DSS(I-1)
 16     CONTINUE
        IF(NMISS.GT.0) WRITE (6,31) NMISS
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      IF(DMAX/DRA.GT.100.0) GO TO 18
      RINTR=DRA**0.2
      RINTR=RINTR*2.
      IF(RINTR.LE.4.0) INTRVL=3
      IF(RINTR.LE.6.0.AND.RINTR.GT.4.0) INTRVL=5
      IF(RINTR.LE.8.0.AND.RINTR.GT.6.0) INTRVL=7
      IF(RINTR.LE.10.0.AND.RINTR.GT.8.0) INTRVL=9
      IF(RINTR.GT.10.0) INTRVL=11
      CALL REREAD
      GO TO 1
C     ****************************************************************
 17   WRITE (6,27) N
      GO TO 20
 18   WRITE (6,28) DMAX,DRA
      GO TO 20
C
 19   STOP
C
 20   CONTINUE
C     FLUSH TO NEXT 'READ' CARD.
      FLUSH=.TRUE.
      CALL REREAD
      GO TO 1
C
C
C
 21   FORMAT (20A4)
 22   FORMAT (//,1X,20A4)
 23   FORMAT (T22,A4)
 24   FORMAT (' THE INPUT CARD PRINTED ABOVE IS NOT ONE OF THE',' ALLOWA
     1BLE STATEMENTS.'/,' THIS BASIN IS THEREFORE ABORTED.')
 25   FORMAT (T1,16A4,2X,F8.0,3X,I3)
 26   FORMAT (36(10(F8.0)/),5(F8.0))
 27   FORMAT ('0','***** ERROR *****  N IS ',I3,'.  THIS PROGRAM IS DESI
     1GNED FOR WATER YEARS OF 365 DAYS'/'0',' BEGINNING IN OCTOBER.  PLE
     2ASE USE ANOTHER PROGRAM FOR OTHER TYPES OF RECORDS.')
 28   FORMAT ('0','***** ERROR *****  MAXIMUM DISCHARGE IS ',F10.0,'. DR
     1AINAGE AREA IS ',F8.2,'.  '/'0','          THE RATIO DISCHARGE/DR
     2AINAGE AREA EXCEEDS 100 CFS/SQ.MI.')
 29   FORMAT ('0',' ******************************************************'
     1)
 30   FORMAT ('0',2X,16A4,2X,F8.2,2X,I3)
 31   FORMAT ('0',' ***** NOTE ***** THERE ARE ',I3,' DAYS THAT HAVE MIS
     1SING DATA.  VALUES FOR THESE DAYS HAVE BEEN'/'0',' SET TO THE LAST
     2 VALID DATA VALUES.  INSPECT OUTPUT CAREFULLY.')
      END
      SUBROUTINE FXINTR
      DIMENSION SECH(6)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA SECH(2),SECH(3),SECH(4),SECH(5),SECH(6)/'DAY ','FIXE','D IN',
     1'TERV','AL  '/
      DATA THREE,FIVE,SEVEN,NINE,ELEVEN/' 3  ',' 5  ',' 7  ',' 9  ',' 11
     1 '/
      DO 1 J=2,6
 1    TECH(J)=SECH(J)
      IF(INTRVL.EQ.3) TECH(1)=THREE
      IF(INTRVL.EQ.5) TECH(1)=FIVE
      IF(INTRVL.EQ.7) TECH(1)=SEVEN
      IF(INTRVL.EQ.9) TECH(1)=NINE
      IF(INTRVL.EQ.11) TECH(1)=ELEVEN
      WRITE (6,8) INTRVL
      K=365/INTRVL
      DO 4 I=1,K
      PMIN=100000.
      L1=((I-1)*INTRVL)+1
      L2=I*INTRVL
      DO 2 J=L1,L2
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
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```
 2    CONTINUE
      DO 3 J=L1,L2
      GDIS(J)=PMIN
 3    CONTINUE
 4    CONTINUE
      M1=(K*INTRVL)+1
      IF(K*INTRVL.EQ.365) GO TO 7
      PMIN=100000.
      DO 5 J=M1,365
      IF(DSS(J).LT.0.0) GO TO 5
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
 5    CONTINUE
      DO 6 J=M1,365
      IF(DSS(J).LT.0.0) GO TO 6
      GDIS(J)=PMIN
 6    CONTINUE
 7    RETURN
C
C
C
 8    FORMAT ('0','FIXED INTERVAL, INTERVAL=',I3,' DAYS')
      END
      SUBROUTINE SLINTR
      DIMENSION SECH(6)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA SECH(2),SECH(3),SECH(4),SECH(5),SECH(6)/'DAY ','SLID','ING ',
     1'INTE','RVAL'/
      DATA THREE,FIVE,SEVEN,NINE,ELEVEN/' 3  ',' 5  ',' 7  ',' 9  ',' 11
     1 '/
      DO 1 J=2,6
 1    TECH(J)=SECH(J)
      INT=INTRVL
      IF(INT.EQ.3) TECH(1)=THREE
      IF(INT.EQ.5) TECH(1)=FIVE
      IF(INT.EQ.7) TECH(1)=SEVEN
      IF(INT.EQ.9) TECH(1)=NINE
      IF(INT.EQ.11) TECH(1)=ELEVEN
      WRITE (6,10) INTRVL
      INT=(INTRVL-1)/2
      DO 9 I=1,365
      IF(DSS(I).LT.0.0) GO TO 9
      IF(I-(INT+1)) 5,2,2
 2    IF((365-I)-(INT+1)) 7,3,3
 3    PMIN=100000.
      K1=I-INT
      K2=I+INT
      DO 4 J=K1,K2
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
 4    CONTINUE
      GDIS(I)=PMIN
      GO TO 9
 5    PMIN=100000.
      K2=I+INT
      DO 6 J=1,K2
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
 6    CONTINUE
      GDIS(I)=PMIN
      GO TO 9
 7    PMIN=100000.
      K1=I-INT
      DO 8 J=K1,365
      IF(DSS(J).LT.PMIN) PMIN=DSS(J)
 8    CONTINUE
      GDIS(I)=PMIN
 9    CONTINUE
      RETURN
C
C
```

```
C
 10   FORMAT ('0','SLIDING INTERVAL, INTERVAL=',I3,' DAYS')
      END
      SUBROUTINE LOCMIN
      DIMENSION IPOINT(400), SECH(6)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA SECH(2),SECH(3),SECH(4),SECH(5),SECH(6)/'DAY ','LOCA','L MI',
     1'NIMA','    '/
      DATA THREE,FIVE,SEVEN,NINE,ELEVEN/' 3  ',' 5  ',' 7  ',' 9  ',' 11
     1 '/
      DO 1 J=2,6
 1    TECH(J)=SECH(J)
      INT=INTRVL
      IF(INT.EQ.3) TECH(1)=THREE
      IF(INT.EQ.5) TECH(1)=FIVE
      IF(INT.EQ.7) TECH(1)=SEVEN
      IF(INT.EQ.9) TECH(1)=NINE
      IF(INT.EQ.11) TECH(1)=ELEVEN
      WRITE (6,24) INTRVL
      NUMPT=0
      IF(INTRVL.EQ.3) GO TO 2
      IF(INTRVL.EQ.5) GO TO 5
      IF(INTRVL.EQ.7) GO TO 8
      IF(INTRVL.EQ.9) GO TO 11
      IF(INTRVL.GE.11) GO TO 14
 2    L=365-1
      DO 4 I=2,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I-1)) GO TO 3
      GO TO 4
 3    NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
 4    CONTINUE
      GO TO 17
 5    L=365-2
      DO 7 I=3,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I-1).AND.DSS(I).LE.DSS(I+2
     1).AND.DSS(I).LE.DSS(I-2)) GO TO 6
      GO TO 7
 6    NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
 7    CONTINUE
      GO TO 17
 8    L=365-3
      DO 10 I=4,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I+2).AND.DSS(I).LE.DSS(I+3
     1).AND.DSS(I).LE.DSS(I-1).AND.DSS(I).LE.DSS(I-2).AND.DSS(I).LE.DSS(
     2I-3)) GO TO 9
      GO TO 10
 9    NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
 10   CONTINUE
      GO TO 17
 11   L=365-4
      DO 13 I=5,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I+2).AND.DSS(I).LE.DSS(I+3
     1).AND.DSS(I).LE.DSS(I-1).AND.DSS(I).LE.DSS(I-2).AND.DSS(I).LE.DSS(
     2I-3).AND.DSS(I).LE.DSS(I-4).AND.DSS(I).LE.DSS(I+4)) GO TO 12
      GO TO 13
 12   NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
 13   CONTINUE
      GO TO 17
 14   L=365-5
      DO 16 I=6,L
      IF(DSS(I).LE.DSS(I+1).AND.DSS(I).LE.DSS(I+2).AND.DSS(I).LE.DSS(I+3
     1).AND.DSS(I).LE.DSS(I-1).AND.DSS(I).LE.DSS(I-2).AND.DSS(I).LE.DSS(
     2I-3).AND.DSS(I).LE.DSS(I-4).AND.DSS(I).LE.DSS(I+4).AND.DSS(I).LE.D
     3SS(I-5).AND.DSS(I).LE.DSS(I+5)) GO TO 15
```

```
      GO TO 16
 15   NUMPT=NUMPT+1
      IPOINT(NUMPT)=I
 16   CONTINUE
 17   K=NUMPT-1
      J=IPOINT(1)
      L=IPOINT(NUMPT)
      DO 18 IJ=1,J
      GDIS(IJ)=DSS(J)
 18   CONTINUE
      DO 19 IJ=L,365
      GDIS(IJ)=DSS(L)
 19   CONTINUE
      DO 21 I=1,K
      IP1=IPOINT(I)
      IP2=IPOINT(I+1)
      GDIS(IP1)=DSS(IP1)
      GDIS(IP2)=DSS(IP2)
      ISTART=IP1
      IEND=IP2
      DO 20 J=ISTART,IEND
      X=J-IP1
      Y=IP2-IP1
      IF(GDIS(IP1).EQ.0.0) GDIS(IP1)=0.01
      IF(GDIS(IP2).EQ.0.0) GDIS(IP2)=0.01
      GDIS(J)=10.**((X/Y)*(ALOG10(GDIS(IP2))-ALOG10(GDIS(IP1)))+ALOG10(G
     1DIS(IP1)))
 20   CONTINUE
 21   CONTINUE
      DO 22 IJK=1,365
      IF(GDIS(IJK).GT.DSS(IJK)) GDIS(IJK)=DSS(IJK)
 22   CONTINUE
      RETURN
C
C
C
 24   FORMAT ('0','LOCAL MINIMA. INTERVAL=',I3,' DAYS')
      END
      SUBROUTINE STATGW
C      * * THIS SUBROUTINE CALCULATES AND PRINTS OUT SUMMARY
C         INFORMATION ABOUT THE SEPARATION.  IT IS ONLY TO BE USED
C         AFTER ONE OF THE SEPARATION TECHNIQUES HAS BEEN CALLED.
      REAL MDSS,LMIN,LMAX
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DAYS=0.0
      LMIN=100000.
      LMAX=.0
      TOTDIS=.0
      TOTGW=0.0
      DO 1 I=1,365
      IF(DSS(I).LT.0.0) GO TO 1
      DAYS=DAYS+1
      TOTDIS=TOTDIS+DSS(I)
      TOTGW=TOTGW+GDIS(I)
      IF(DSS(I).LT.LMIN) LMIN=DSS(I)
      IF(DSS(I).GT.LMAX) LMAX=DSS(I)
 1    CONTINUE
      TOQUAN=86400.*TOTDIS
      TOQUGW=86400.*TOTGW
      TOTGWI=0.03719*(TOTGW/DRA)
      TOTQIN=0.03719*(TOTDIS/DRA)
      MDSS=TOTDIS/DAYS
      WRITE (6,2)
      WRITE (6,3) TOQUAN,TOTQIN
      WRITE (6,4) LMIN
      WRITE (6,5) MDSS
      WRITE (6,6) LMAX
      TDSSMI=TOQUAN/DRA
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      TDGWSM=TOQUGW/DRA
      WRITE (6,7) TDSSMI
      WRITE (6,8) TOQUGW,TOTGWI
      WRITE (6,9) TDGWSM
      PERCEN=(TOQUGW/TOQUAN)*100.
      WRITE (6,10) PERCEN
      RECH=TDGWSM*7.48/DAYS
      IRECH=IFIX(RECH/1000.)
      RECHG=FLOAT(IRECH*1000)
      IF(RECH.LE.10000) RECHG=RECH
      WRITE (6,11) RECHG
      WRITE (6,12)
      RETURN
C
C
C
 2    FORMAT ('0')
 3    FORMAT ('0','TOTAL DISCHARGE FOR THE WATER YEAR',11X,1PE10.3,1X,'C
     1F',20X,'OR  ',0PF7.2,'  INCHES')
 4    FORMAT ('0','MINIMUM DISCHARGE',30X,F8.2,1X,'CFS')
 5    FORMAT ('0','MEAN DISCHARGE',33X,F8.2,1X,'CFS')
 6    FORMAT ('0','MAXIMUM DISCHARGE',30X,F8.2,1X,'CFS')
 7    FORMAT ('0','TOTAL DISCHARGE/YR/BASIN AREA',16X,1PE10.3,1X,'CF/SQ.
     1MI')
 8    FORMAT ('0','THE TOTAL GROUND WATER DISCHARGE FOR A YEAR',2X,1PE10
     1.3,1X,'CF',20X,'OR  ',0PF7.2,'  INCHES')
 9    FORMAT ('0','TOTAL GROUND WATER DISCHARGE/YR/BASIN AREA',3X,1PE10.
     13,1X,'CF /SQ.MI.')
 10   FORMAT ('0','% OF TOTAL DISCHARGE DUE TO GROUND WATER RUNOFF',F7.2
     1)
 11   FORMAT ('0',60X,'THE RECHARGE RATE  = ',F10.0,'   GPD/SQ.MI.')
 12   FORMAT ('0','* * * * * * * * * * * * * * * * * * * * '/)
      END
      SUBROUTINE MONTHS
C       * * THIS SUBROUTINE CALCULATES INFORMATION ABOUT THE
C          SEPARATION ON A MONTHLY BASIS.  IT IS TO BE USED ONLY
C          AFTER A SEPARATION SUBROUTINE HAS BEEN CALLED.
      DIMENSION MONTH(12,6)
      REAL MONTH
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      TOTALQ=0.000000000000001
      TOTLGW=0.0
      DO 2 I=1,12
      DO 1 J=1,6
      MONTH(I,J)=0.0
 1    CONTINUE
 2    CONTINUE
      DO 3 I=1,31
      IF(DSS(I).LT.0.0) GO TO 3
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
 3    CONTINUE
      MONTH(1,1)=TOTALQ*86400.
      MONTH(1,2)=0.03719*(TOTALQ/DRA)
      MONTH(1,3)=TOTLGW*86400.
      MONTH(1,4)=0.03719*(TOTLGW/DRA)
      MONTH(1,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(1,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(1,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 4 I=32,61
      IF(DSS(I).LT.0.0) GO TO 4
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
 4    CONTINUE
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```
      MONTH(2,1)=TOTALQ*86400.
      MONTH(2,2)=0.03719*(TOTALQ/DRA)
      MONTH(2,3)=TOTLGW*86400.
      MONTH(2,4)=0.03719*(TOTLGW/DRA)
      MONTH(2,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/30.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(2,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(2,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 5 I=62,92
      IF(DSS(I).LT.0.0) GO TO 5
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
5     CONTINUE
      MONTH(3,1)=TOTALQ*86400.
      MONTH(3,2)=0.03719*(TOTALQ/DRA)
      MONTH(3,4)=0.03719*(TOTLGW/DRA)
      MONTH(3,3)=TOTLGW*86400.
      MONTH(3,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(3,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(3,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 6 I=93,123
      IF(DSS(I).LT.0.0) GO TO 6
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
6     CONTINUE
      MONTH(4,1)=TOTALQ*86400.
      MONTH(4,3)=TOTLGW*86400.
      MONTH(4,2)=0.03719*(TOTALQ/DRA)
      MONTH(4,4)=0.03719*(TOTLGW/DRA)
      MONTH(4,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(4,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(4,6)=RECH
      TOTALQ=0.00000000001
      TOTLGW=0.0
      DO 7 I=124,151
      IF(DSS(I).LT.0.0) GO TO 7
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
7     CONTINUE
      MONTH(5,1)=TOTALQ*86400.
      MONTH(5,2)=0.03719*(TOTALQ/DRA)
      MONTH(5,3)=TOTLGW*86400.
      MONTH(5,4)=0.03719*(TOTLGW/DRA)
      MONTH(5,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/28.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(5,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(5,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 8 I=152,182
      IF(DSS(I).LT.0.0) GO TO 8
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
8     CONTINUE
      MONTH(6,1)=TOTALQ*86400.
      MONTH(6,2)=0.03719*(TOTALQ/DRA)
      MONTH(6,3)=TOTLGW*86400.
      MONTH(6,4)=0.03719*(TOTLGW/DRA)
```

```
      MONTH(6,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(6,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(6,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 9 I=183,212
      IF(DSS(I).LT.0.0) GO TO 9
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
9     CONTINUE
      MONTH(7,1)=TOTALQ*86400.
      MONTH(7,2)=0.03719*(TOTALQ/DRA)
      MONTH(7,3)=TOTLGW*86400.
      MONTH(7,4)=0.03719*(TOTLGW/DRA)
      MONTH(7,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/30.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(7,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(7,6)=RECH
      TOTALQ=0.00000000001
      TOTLGW=0.0
      DO 10 I=213,243
      IF(DSS(I).LT.0.0) GO TO 10
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
10    CONTINUE
      MONTH(8,1)=TOTALQ*86400.
      MONTH(8,2)=0.03719*(TOTALQ/DRA)
      MONTH(8,3)=TOTLGW*86400.
      MONTH(8,5)=(TOTLGW/TOTALQ)*100.
      MONTH(8,4)=0.03719*(TOTLGW/DRA)
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(8,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(8,6)=RECH
      TOTLGW=0.0
      TOTALQ=0.000000000001
      DO 11 I=244,273
      IF(DSS(I).LT.0.0) GO TO 11
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
11    CONTINUE
      MONTH(9,1)=TOTALQ*86400.
      MONTH(9,2)=0.03719*(TOTALQ/DRA)
      MONTH(9,3)=TOTLGW*86400.
      MONTH(9,4)=0.03719*(TOTLGW/DRA)
      MONTH(9,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/30.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(9,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(9,6)=RECH
      TOTALQ=0.00000000001
      TOTLGW=0.0
      DO 12 I=274,304
      IF(DSS(I).LT.0.0) GO TO 12
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
12    CONTINUE
      MONTH(10,1)=TOTALQ*86400.
      MONTH(10,2)=0.03719*(TOTALQ/DRA)
      MONTH(10,3)=TOTLGW*86400.
      MONTH(10,4)=0.03719*(TOTLGW/DRA)
      MONTH(10,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(10,6)=FLOAT(IRECH*1000)
```

```
      IF(RECH.LE.10000.) MONTH(10,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 13 I=305,335
      IF(DSS(I).LT.0.0) GO TO 13
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
   13 CONTINUE
      MONTH(11,1)=TOTALQ*86400.
      MONTH(11,2)=0.03719*(TOTALQ/DRA)
      MONTH(11,3)=TOTLGW*86400.
      MONTH(11,4)=0.03719*(TOTLGW/DRA)
      MONTH(11,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/31.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(11,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(11,6)=RECH
      TOTALQ=0.000000000001
      TOTLGW=0.0
      DO 14 I=336,365
      IF(DSS(I).LT.0.0) GO TO 14
      TOTALQ=TOTALQ+DSS(I)
      TOTLGW=TOTLGW+GDIS(I)
   14 CONTINUE
      MONTH(12,1)=TOTALQ*86400.
      MONTH(12,2)=0.03719*(TOTALQ/DRA)
      MONTH(12,3)=TOTLGW*86400.
      MONTH(12,4)=0.03719*(TOTLGW/DRA)
      MONTH(12,5)=(TOTLGW/TOTALQ)*100.
      RECH=(TOTLGW/DRA)*7.48/30.*86400.
      IRECH=IFIX(RECH/1000.)
      MONTH(12,6)=FLOAT(IRECH*1000)
      IF(RECH.LE.10000.) MONTH(12,6)=RECH
      WRITE (6,15)
      WRITE (6,16) (MONTH(I,1),I=1,12)
      WRITE (6,17) (MONTH(I,2),I=1,12)
      WRITE (6,18) (MONTH(I,3),I=1,12)
      WRITE (6,19) (MONTH(I,4),I=1,12)
      WRITE (6,20) (MONTH(I,5),I=1,12)
      WRITE (6,21) (MONTH(I,6),I=1,12)
      WRITE (6,22)
      RETURN
C
C
C
   15 FORMAT ('0',15X,'OCT',7X,'NOV',7X,'DEC',7X,'JAN',7X,'FEB',7X,'MAR'
     1,7X,'APR',7X,'MAY',7X,'JUN',7X,'JUL',7X,'AUG',7X,'SEP')
   16 FORMAT ('0','TOTAL Q(CF) ',12(1PE10.2))
   17 FORMAT ('0','TOTAL Q(IN) ',12(F10.3))
   18 FORMAT ('0','GW (CF )    ',12(1PE10.2))
   19 FORMAT ('0','GW (IN )    ',12(F10.3))
   20 FORMAT ('0','% AS G W    ',12(F10.2))
   21 FORMAT ('0','RR GPD/MI2  ',12(F10.0))
   22 FORMAT ('0','* * * * * * * * * * * * * * * * * * * * * * * * * * * *'/
     1)
      END
      SUBROUTINE VERSAP
C     *  THIS SUBROUTINE PRODUCES OUTPUT ON THE VERSATEC PLOTTER ****
      DIMENSION BCD(3)
      DIMENSION TOTAL(4), GROUND(6), GROUNP(5), RECHAR(4), CF(5), GPD(3)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA BCD/'LOG ','M 3 ','/S  '/
      DATA TOTAL/'TOTA','L DI','SCHA','RGE '/
      DATA GROUND/'GROU','ND W','ATER',' RUN','OFF ','    '/
      DATA GROUNP/'GROU','ND W','ATER',' AS ','%   '/
      DATA RECHAR/'RECH','ARGE',' RAT','E   '/
      DATA CF/'CF O','R   ','    ','  IN','CHES'/
      DATA GPD/'GPD ','/SQ.',' MI.'/
```

```
C       ** CALCULATE SUMMARY INFORMATION                              **********
        DIMENSION TITLE(16)
        DAYS=0.0
        TOTDIS=.0
        RMAX=0.0
        RMIN=100000000.
        TOTGW=0.0
        DO 1 I=1,365
        DAYS=DAYS+1.0
        IF(DSS(I).GT.RMAX) RMAX=DSS(I)
        IF(DSS(I).LT.RMIN) RMIN=DSS(I)
        TOTDIS=TOTDIS+DSS(I)
        TOTGW=TOTGW+GDIS(I)
 1      CONTINUE
        TOQUAN=86400.*TOTDIS
        TOQUGW=86400.*TOTGW
        TOTGWI=0.03719*(TOTGW/DRA)
        TOTQIN=0.03719*(TOTDIS/DRA)
        TDSSMI=TOQUAN/DRA
        TDGWSM=TOQUGW/DRA
        PERCEN=(TOQUGW/TOQUAN)*100.
        RECH=TDGWSM*7.48/DAYS
        IRECH=IFIX(RECH/1000.)
        RECHG=FLOAT(IRECH*1000)
        IF(RECH.LE.10000) RECHG=RECH
        XQUAN=ALOG10(TOQUAN)
        YQUAN=IFIX(XQUAN)
        TOQUAN=10**(XQUAN-YQUAN)
        TOTQE=YQUAN
        XQUGW=ALOG10(TOQUGW)
        YQUGW=IFIX(XQUGW)
        TOQUGW=10**(XQUGW-YQUGW)
        TOQGWE=YQUGW
        DO 2 J=1,16
 2      TITLE(J)=STA(J)
C       ** PLOTTING OF HYDROGRAPH  (USING OSU GPP EMULATOR) ***********
        CALL AXSN (1.0,1.0,'DAYS',-4,9.125,0.,0.,40.,0.75,2,-1)
        CALL AXSN (1.,1.,'LOG DISCHARGE,CFS',17,5.,90.,-2.,1.6,0.625,0,1)
        CALL PLOT (1.0,1.0,3)
        DO 3 I=1,365
        IC=2
        IF(I.EQ.1) IC=3
        X=1.025+I*(.025)
        IF(DSS(I).EQ.0.0) DSS(I)=0.01
        IF(DSS(I).LT.0.01) IC=3
        Y=2.25+(ALOG10(DSS(I))/1.6)
        CALL PLOT (X,Y,IC)
 3      CONTINUE
        CALL PLOT (0.0,0.0,3)
        DO 4 I=1,365
        IC=2
        IF(I.EQ.1) IC=3
        X=1.025+I*(.025)
        IF(GDIS(I).EQ.0.0) GDIS(I)=0.01
        IF(GDIS(I).LT.0.01) IC=3
        Y=2.25+(ALOG10(GDIS(I))/1.6)
        CALL PLOT (X,Y,IC)
 4      CONTINUE
        CALL AXSN (10.150,1.,'DISCHARGE',-0,-5.,90.,-2.,1.6,0.625,0,1)
        CALL AXSN (10.3,1.343,BCD,-12,5.,90.,-3.,1.6,0.625,0,1)
        CALL AXSN (10.000,6.000,'DAYS',0,-9.125,180.,0.,40.,0.75,2,-1)
        IF(RMIN.GT.1.0) GO TO 5
        IF(RMAX.LT.10000) GO TO 6
        IF(RMAX.LT.100000.AND.RMIN.GT.0.1) GO TO 7
        GO TO 8
 5      CALL SYMBOL (2.0,1.25,0.14,RECHAR,0.0,16)
        CALL NUMBER (4.5,1.25,0.14,RECHG,0.0,-1)
        CALL SYMBOL (6.5,1.25,0.14,GPD,0.0,12)
```

```
      CALL SYMBOL (2.0,1.50,0.14,GROUNP,0.0,20)
      CALL NUMBER (5.1,1.50,0.14,PERCEN,0.0,1)
      CALL SYMBOL (2.0,1.75,0.14,GROUND,0.0,24)
      CALL NUMBER (5.1,1.75,0.14,TOQUGW,0.0,3)
      CALL SYMBOL (5.85,1.75,0.14,69,0.0,-1)
      CALL NUMBER (6.1,1.75,0.14,TOQGWE,0.0,-1)
      CALL SYMBOL (2.0,2.00,0.14,TOTAL,0.0,16)
      CALL NUMBER (5.1,2.00,0.14,TOQUAN,0.0,3)
      CALL SYMBOL (5.85,2.00,0.14,69,0.0,-1)
      CALL NUMBER (6.1,2.00,0.14,TOTQE,0.0,-1)
      CALL SYMBOL (6.7,1.75,0.14,CF,0.0,20)
      CALL NUMBER (7.6,1.75,0.14,TOTGWI,0.0,2)
      CALL SYMBOL (6.7,2.00,0.14,CF,0.0,20)
      CALL NUMBER (7.6,2.00,0.14,TOTQIN,0.0,2)
      GO TO 8
6     CALL SYMBOL (2.0,4.75,0.14,RECHAR,0.0,16)
      CALL NUMBER (4.5,4.75,0.14,RECHG,0.0,-1)
      CALL SYMBOL (6.5,4.75,0.14,GPD,0.0,12)
      CALL SYMBOL (2.0,5.00,0.14,GROUNP,0.0,20)
      CALL NUMBER (5.1,5.00,0.14,PERCEN,0.0,1)
      CALL SYMBOL (2.0,5.25,0.14,GROUND,0.0,24)
      CALL NUMBER (5.1,5.25,0.14,TOQUGW,0.0,3)
      CALL SYMBOL (5.85,5.25,0.14,69,0.0,-1)
      CALL NUMBER (6.1,5.25,0.14,TOQGWE,0.0,-1)
      CALL SYMBOL (2.0,5.50,0.14,TOTAL,0.0,16)
      CALL NUMBER (5.1,5.50,0.14,TOQUAN,0.0,3)
      CALL SYMBOL (5.85,5.50,0.14,69,0.0,-1)
      CALL NUMBER (6.1,5.50,0.14,TOTQE,0.0,-1)
      CALL SYMBOL (6.7,5.25,0.14,CF,0.0,20)
      CALL NUMBER (7.6,5.25,0.14,TOTGWI,0.0,2)
      CALL SYMBOL (6.7,5.50,0.14,CF,0.0,20)
      CALL NUMBER (7.6,5.50,0.14,TOTQIN,0.0,2)
      GO TO 8
7     CALL SYMBOL (2.0,1.25,0.14,RECHAR,0.0,16)
      CALL NUMBER (4.5,1.25,0.14,RECHG,0.0,-1)
      CALL SYMBOL (6.5,1.25,0.14,GPD,0.0,12)
      CALL SYMBOL (2.0,1.50,0.14,GROUNP,0.0,20)
      CALL NUMBER (5.1,1.50,0.14,PERCEN,0.0,1)
      CALL SYMBOL (2.0,5.25,0.14,GROUND,0.0,24)
      CALL NUMBER (5.1,5.25,0.14,TOQUGW,0.0,3)
      CALL SYMBOL (5.85,5.25,0.14,69,0.0,-1)
      CALL NUMBER (6.1,5.25,0.14,TOQGWE,0.0,-1)
      CALL SYMBOL (2.0,5.50,0.14,TOTAL,0.0,16)
      CALL NUMBER (5.1,5.50,0.14,TOQUAN,0.0,3)
      CALL SYMBOL (5.85,5.50,0.14,69,0.0,-1)
      CALL NUMBER (6.1,5.50,0.14,TOTQE,0.0,-1)
      CALL SYMBOL (6.7,5.25,0.14,CF,0.0,20)
      CALL NUMBER (7.6,5.25,0.14,TOTGWI,0.0,2)
      CALL SYMBOL (6.7,5.50,0.14,CF,0.0,20)
      CALL NUMBER (7.6,5.50,0.14,TOTQIN,0.0,2)
8     CONTINUE
      CALL SYMBOL (1.000,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (1.317,6.050,0.07,'OCT',0.0,3)
      CALL SYMBOL (1.775,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (2.525,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (3.300,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (3.617,6.050,0.07,'JAN',0.0,3)
      CALL SYMBOL (4.075,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (4.775,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (5.550,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (5.867,6.050,0.07,'APR',0.0,3)
      CALL SYMBOL (6.300,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (7.075,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (7.825,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (8.142,6.050,0.07,'JUL',0.0,3)
      CALL SYMBOL (8.600,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (9.375,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (9.692,6.050,0.07,'SEP',0.0,3)
```

```
      CALL SYMBOL (10.125,6.000,0.07,90,0.0,-1)
      CALL SYMBOL (1.,6.5,0.14,TECH,0.,24)
      CALL SYMBOL (1.,7.,.14,TITLE,0.0,64)
      CALL NUMBER (9.25,6.5,0.14,DRA,0.0,1)
      CALL SYMBOL (10.25,6.5,0.14,'SQ.MI.',0.0,6)
      IF(NMISS.GT.0) GO TO 9
      CALL PLOT (12.0,0.0,-3)
      CALL PLOTE2
      RETURN
    9 RMISS=FLOAT(NMISS)
      CALL NUMBER (6.5,6.5,0.14,RMISS,0.0,-1)
      CALL SYMBOL (7.0,6.5,0.14,' MISSING DAYS',0.0,13)
      CALL PLOT (12.0,0.0,-3)
      CALL PLOTE2
      RETURN
      END
      SUBROUTINE PUNCHR
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      WRITE (7,2) STA,DRA
      TOTDIS=.0
      TOTGW=0.0
      DO 1 I=1,365
      IF(DSS(I).LT.0.0) GO TO 1
      TOTDIS=TOTDIS+DSS(I)
      TOTGW=TOTGW+GDIS(I)
    1 CONTINUE
      TOQUAN=86400.*TOTDIS
      TOQUGW=86400.*TOTGW
      TOTGWI=0.03719*(TOTGW/DRA)
      TOTQIN=0.03719*(TOTDIS/DRA)
      TDISMI=TOQUAN/DRA
      TDGWSM=TOQUGW/DRA
      PERCEN=(TOQUGW/TOQUAN)*100.
      RECH=TDGWSM*7.48/365.
      IRECH=IFIX(RECH/1000.)
      RECHG=FLOAT(IRECH*1000)
      IF(RECH.LE.10000) RECHG=RECH
      WRITE (7,3) TOQUAN,TOQUGW,TOTQIN,TOTGWI,PERCEN,RECHG
      WRITE (7,4) GDIS
      RETURN
C
C
    2 FORMAT (16A4,F8.2)
    3 FORMAT (E10.3,E10.3,F7.2,F7.2,F5.1,F9.0)
    4 FORMAT (10(F8.0))
      END
      SUBROUTINE FLWDUR
      INTEGER PER(365),PLOT(101,120),DOT,PLUS,BLANK,CAPI
      DIMENSION DISDEN(365), INDX(365), APER(365)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA BLANK/'    '/,PLUS/'++++'/,DOT/'....'/,CAPI/'IIII'/
      WRITE (6,16) STA,DRA
      M=365-1
      DO 2 I=1,M
      L=365-1
      DO 1 J=1,L
      IF(DSS(J).LE.DSS(J+1)) GO TO 1
      X=DSS(J)
      DSS(J)=DSS(J+1)
      DSS(J+1)=X
    1 CONTINUE
    2 CONTINUE
      DO 7 I=1,101
      DO 3 J=1,120
      PLOT(I,J)=BLANK
    3 CONTINUE
      PLOT(I,120)=CAPI
      IF(I/2.-I/2) 4,4,5
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 4    PLOT(I,18)=DOT
      PLOT(I,36)=DOT
      PLOT(I,54)=DOT
      PLOT(I,60)=DOT
      PLOT(I,78)=DOT
      PLOT(I,96)=DOT
      PLOT(I,114)=DOT
 5    CONTINUE
      IF(I.EQ.1) GO TO 7
      IF(I.EQ.101) GO TO 7
      IF(MOD(I,10).NE.1) GO TO 7
      DO 6 J=2,118,2
      PLOT(I,J)=DOT
 6    CONTINUE
 7    CONTINUE
      DO 8 I=1,365
      APER(I)=(365-I+1.)*100/365
      PER(I)=IFIX((365-I+1.)*100/365+.5)
      DISDEN(I)=DSS(I)/DRA
      IF(DISDEN(I).LE..1) GO TO 8
      INDX(I)=IFIX(60.*ALOG10(DISDEN(I))+60.5)
      IF(INDX(I).GT.120) GO TO 8
      PLOT(PER(I)+1,INDX(I))=PLUS
 8    CONTINUE
      WRITE (6,17)
      WRITE (6,18)
      WRITE (6,19)
      DO 10 I=1,101
      KI=I-1
      IF(I.GT.1) GO TO 9
      WRITE (6,20) KI,(PLOT(I,J),J=1,120)
      GO TO 10
 9    WRITE (6,21) KI,(PLOT(I,J),J=1,120)
 10   CONTINUE
      WRITE (6,22)
      WRITE (6,16) STA,DRA
      WRITE (6,23)
      DO 11 I=1,365,8
      IF(I.EQ.361) GO TO 12
      II=I+7
      WRITE (6,24) (APER(N),DISDEN(N),N=I,II)
 11   CONTINUE
 12   WRITE (6,25) (APER(N),DISDEN(N),N=361,365)
      DELTA1=DISDEN(37)-DISDEN(36)
      DELTA2=DISDEN(329)-DISDEN(328)
      DELTA3=DISDEN(92)-DISDEN(91)
      DELTA4=DISDEN(274)-DISDEN(273)
      Q90=DISDEN(36)+(DELTA1/2)
      Q10=DISDEN(328)+(DELTA2/2)
      Q75=DISDEN(91)+(DELTA3/4)
      Q25=DISDEN(274)-(DELTA4/4)
      IF(Q90.LE.0.) GO TO 13
      IF(Q75.LE.0.) GO TO 14
      GO TO 15
 13   WRITE (6,27)
      IF(Q90.LE.0.) Q90=0.001
      GO TO 15
 14   WRITE (6,28)
      IF(Q75.LE.0.) Q75=0.001
      GO TO 15
 15   RT1090=SQRT(Q10/Q90)
      RT2575=SQRT(Q25/Q75)
      WRITE (6,26) RT1090,RT2575
      RETURN
C
C
 16   FORMAT ('1','FLOW-DURATION CURVE FOR',17X,16A4,2X,F8.2,2X,'SQ.MI')
 17   FORMAT ('0','PERCENT',48X,'FLOW CFS/SQ MI')
```

```
 18   FORMAT ('0',2X,'TIME',3X,'.1',16X,'.2',16X,'.4',16X,'.8',3X,'1.0',
     116X,'2',17X,'4',17X,'8',4X,'10')
 19   FORMAT ('0',9X,2('*',17('-'),'*',17('-'),'*',17('-'),'*',5('-')),'
     1*')
 20   FORMAT ('+',4X,I3,2X,'I',120A1)
 21   FORMAT (' ',4X,I3,2X,'I',120A1)
 22   FORMAT ('+',9X,2('*',17('-'),'*',17('-'),'*',17('-'),'*',5('-')),'
     1*')
 23   FORMAT ('0')
 24   FORMAT (' ',4X,8(F6.2,1X,F6.3,3X))
 25   FORMAT (' ',4X,5(F6.2,1X,F6.3,3X))
 26   FORMAT ('0',7X,'THE RATIO (Q10/Q90)**1/2 =',F8.2,10X,'(Q25/Q75)**1
     1/2 =',F8.2)
 27   FORMAT (' ',' Q90 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANINGL
     1ESS.')
 28   FORMAT (' ','   Q75 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANIN
     1GLESS.')
      END
      SUBROUTINE HYDGRH
C       * * THIS SUBROUTINE WRITES OUT THE HYDROGRAPH WITH THE
C           DISCHARGE SHOWN AS PLUSES AND THE GROUND WATER SEPARATION
C           AS ASTERIKS
C     WRITES OUT HYDROGRAPH
C
      INTEGER PLUS,DOT,AST
      DIMENSION MON(365), MAP(120)
      REAL MDIS,LMIN,LMAX
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA BLANK/'    '/,PLUS/'++++'/,DOT/'....'/,AST/'****'/
      DO 1 I=1,365
      MON(I)=BLANK
 1    CONTINUE
C     FIRST, STATION NUMBER AND DRAINAGE AREA
      WRITE (6,10) STA,DRA
C     THEN LABELS
      WRITE (6,11)
C     THIS IS THE LOG SCALE OF THE HYDROGRAPH
      WRITE (6,12)
      WRITE (6,13)
      DO 8 I=1,365
      IF(DSS(I).LE.0.01) DSS(I)=0.01
      IF(GDIS(I).LE.0.01) GDIS(I)=0.01
      DO 2 J=1,119
C
C     MAP= ONE OUTPUT LINE OF THE HYDROGRAPH
C     THIS SECTION CREATES BASIC GRAPH OUTLINE
C
 2    MAP(J)=BLANK
      MAP(120)=PLUS
      IF(MON(I).NE.DOT) GO TO 4
      IF(I.EQ.365) GO TO 4
      DO 3 KI=2,118,2
 3    MAP(KI)=DOT
 4    CONTINUE
      IF(I/2.-I/2) 5,5,6
 5    MAP(40)=DOT
      MAP(80)=DOT
 6    CONTINUE
C
C     THIS SECTION ASSIGNS THE DISCHARGE VALUE A POINT ON THE GRAPH AND
C     OUTPUTS THAT DAY
      IF(DSS(I).LT.0.10) GO TO 7
C     ON THE GRAPH 20 SPACES= 1 LOG CYCLE AND THE LINE STARTS AT -1 LOG
C     CYCLE
      DLOG=20.*ALOG10(DSS(I))+20.
      IF(GDIS(I).LE.0.0) GO TO 7
      GLOG=20.*ALOG10(GDIS(I))+20.
C     THIS STATEMENT ''ROUNDS OFF'' VALUES TO THE NEAREST PRINT POSITION
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      INDX=IFIX(2.*(DLOG-IFIX(DLOG))+IFIX(DLOG))
      INDXC=IFIX(2.*(GLOG-IFIX(GLOG))+IFIX(GLOG))
      MAP(INDX)=PLUS
      MAP(INDXC)=AST
  7   WRITE (6,14) MON(I),MAP,DSS(I)
  8   CONTINUE
C
C     ...AND SOME FINAL LABELS
      WRITE (6,15)
      WRITE (6,12)
C
C     THIS PART OF THE PROGRAM CALCULATES AND PRINTS OUT THE SUMMARY
C     LMIN= MINIMUM DISCHARGE
C     LMAX= MAXIMUM DISCHARGE
C     TOQUAN= TOTAL DISCHARGE IN A YEAR
C     MDIS= MEAN DISCHARGE
      DAYS=0.0
      LMIN=100000.
      LMAX=.0
      TOTDIS=.0
      TOTGW=0.0
      DO 9 I=1,365
      IF(DSS(I).LT.0.0) GO TO 9
      DAYS=DAYS+1.
      TOTDIS=TOTDIS+DSS(I)
      TOTGW=TOTGW+GDIS(I)
      IF(DSS(I).LT.LMIN) LMIN=DSS(I)
      IF(DSS(I).GT.LMAX) LMAX=DSS(I)
  9   CONTINUE
      TOQUAN=86400.*TOTDIS
      TOQUGW=86400.*TOTGW
      MDIS=TOTDIS/DAYS
      WRITE (6,16)
      WRITE (6,17) TOQUAN
      WRITE (6,18) LMIN
      WRITE (6,19) MDIS
      WRITE (6,20) LMAX
      TDISMI=TOQUAN/DRA
      TDGWSM=TOQUGW/DRA
      WRITE (6,21) TDISMI
      WRITE (6,22) TOQUGW
      WRITE (6,23) TDGWSM
      PERCEN=(TOQUGW/TOQUAN)*100.
      WRITE (6,24) PERCEN
      RECH=TDGWSM*7.48/DAYS
      WRITE (6,25) RECH
C
      RETURN
C
C
 10   FORMAT ('0',40X,16A4,2X,F8.2,2X,'SQ.MI')
 11   FORMAT ('0','MONTH',53X,'DISCHARGE, IN CFS')
 12   FORMAT ('0',4X,'.1',18X,'1',18X,'10',17X,'100',15X,'1,000',14X,'10
     1,000',13X,'100,000')
 13   FORMAT ('0',4X,'*',6(19('+'),'*'))
 14   FORMAT (' ',A4,'+',120A1,F7.1)
 15   FORMAT (' ',4X,'*',6(19('+'),'*'))
 16   FORMAT ('0')
 17   FORMAT ('0','TOTAL DISCHARGE FOR THE WATER YEAR',3X,E10.3,1X,'CF')
 18   FORMAT ('0','MINIMUM DISCHARGE',22X,F8.2,1X,'CFS')
 19   FORMAT ('0','MEAN DISCHARGE',25X,F8.2,1X,'CFS')
 20   FORMAT ('0','MAXIMUM DISCHARGE',22X,F8.2,1X,'CFS')
 21   FORMAT ('0','TOTAL DISCHARGE/YR/BASIN AREA',8X,E10.3,1X,'CF/SQ.MI'
     1)
 22   FORMAT ('0','THE TOTAL GROUND WATER DISCHARGE FOR A YEAR',2X,E10.3
     1,1X,'CF ')
 23   FORMAT ('0','TOTAL GROUND WATER DISCHARGE/YR/BASIN AREA',8X,E10.3,
     11X,'CF /SQMI')
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```
 24   FORMAT ('0','% OF TOTAL DISCHARGE DUE TO GROUND WATER RUNOFF',F7.2
     1)
 25   FORMAT ('0',60X,'THE RECHARGE RATE  =  ',E10.3,'    GPD/SQ.MI.')
      END
      SUBROUTINE NDTRI (P,X,D,IE)
C        SEE FORTRAN SSP FOR COMPLETE WRITEUP...
      IE=0
      X=.99999E+74
      D=X
      IF(P) 1,3,2
 1    IE=-1
      GO TO 10
 2    IF(P-1.0) 5,4,1
 3    X=-.99999E+74
 4    D=0.0
      GO TO 10
 5    D=P
      IF(D-0.5) 7,7,6
 6    D=1.0-D
 7    T2=ALOG(1.0/(D*D))
      T=SQRT(T2)
      X=T-(2.515517+0.802853*T+0.010328*T2)/(1.0+1.432788*T+0.189269*T2+
     10.001308*T2)
      IF(P-0.5) 8,8,9
 8    X=-X
 9    D=0.3989423*EXP(-X*X/2.0)
 10   RETURN
      END
      SUBROUTINE VFLWDA
C        THIS SUBROUTINE CALCULATES A FLOW DURATION CURVE FOR
C        THE YEAR AND PRINTS IT OUT ON THE VERSATEC PLOTTER.
C        ON LOGRITHMIC-PROBABILITY PAPER...
      DIMENSION DISDEN(365), INDX(365), APER(365), DIS(365)
      DIMENSION AY(46), AX(23), DDS(365)
      COMMON DRA,DSS(365),GDIS(365),INTRVL,TECH(6),STA(16),NMISS
      DATA AX/.001,.002,.005,.01,.02,.05,.1,.2,.25,.30,.40,.50,.60,.70,.
     175,.80,.90,.95,.98,.99,.995,.998,.999/
      DATA AY/.001,.002,.003,.004,.005,.006,.007,.008,.009,.01,.02,.03,.
     104,.05,.06,.07,.08,.09,.1,.2,.3,.4,.5,.6,.7,.8,.9,1.,2.,3.,4.,5.,6
     2.,7.,8.,9.,10.,20.,30.,40.,50.,60.,70.,80.,90.,100./
       NCNT=1
      RNCNT=FLOAT(NCNT)
C        THIS SECTION CREATES THE BASIC GRAPH OUTLINE...
      CALL PLOT (1.0,1.0,-3)
      CALL SYMBOL (0.0,-1.0,0.14,'PERCENT OF TIME DISCHARGE IS EQUALLED
     1OR EXCEEDED',0.0,49)
      CALL SYMBOL (-1.0,1.0,0.14,'DISCHARGE IN CFS/MI 2',90.0,21)
      DO 5 I=1,46
      YPLOT=(ALOG10(AY(I))*2.25)+6.75
      IF(AY(I).LT.0.01) GO TO 1
      IF(AY(I).LT.0.10) GO TO 2
      IF(AY(I).LT.1.00) GO TO 3
      CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,-1)
      GO TO 4
 1    CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,3)
      GO TO 4
 2    CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,2)
      GO TO 4
 3    CALL NUMBER (-0.5,YPLOT,0.07,AY(I),0.0,1)
 4    CALL PLOT (0.3,YPLOT,3)
      CALL PLOT (9.6,YPLOT,2)
 5    CONTINUE
      DO 8 I=1,23
      CALL NDTRI (AX(I),X,D,IER)
      XPLOT=5.0+X*1.5
      IF(AX(I).LT.0.1.OR.AX(I).GT.0.99) GO TO 6
      CALL NUMBER ((XPLOT-0.07),-0.4,0.07,(100.*AX(I)),0.0,-1)
      GO TO 7
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 6      CALL NUMBER ((XPLOT-0.07),-0.4,0.07,(100.*AX(I)),0.0,1)
 7      CALL PLOT (XPLOT,0.0,3)
        CALL PLOT (XPLOT,11.3,2)
 8      CONTINUE
        NMISS=0
        NOFLOW=0
        MMM=0
        NNM=0
C          DATA SCAN FOR POSSIBLE MISSING DATA OR NO FLOW (<0.01)
        DO 10 I=1,365
        IF(DSS(I).LT.0.0) GO TO 9
        IF(DSS(I).LT.0.01) NOFLOW=NOFLOW+1
        NNM=NNM+1
        DDS(NNM)=DSS(I)
        GO TO 10
 9      NMISS=NMISS+1
 10     CONTINUE
        MMM=MMM+NNM
        M=NNM-1
        DO 12 I=1,M
        L=NNM-1
        DO 11 J=1,L
        IF(DDS(J).LE.DDS(J+1)) GO TO 11
        XR=DDS(J)
        DDS(J)=DDS(J+1)
        DDS(J+1)=XR
 11     CONTINUE
 12     CONTINUE
        DAYS=FLOAT(NNM)
        DO 13 I=1,NNM
        APER(I)=(NNM-I+1.)*100/NNM
        DISDEN(I)=DDS(I)/DRA
 13     CONTINUE
C          WRITES OUT FLOW DURATION TABLE
        WRITE (6,30) STA,DRA
        DO 14 I=1,NNM,8
        IF(NNM.EQ.365.AND.I.EQ.361) GO TO 15
        II=I+7
        WRITE (6,32) (APER(N),DISDEN(N),N=I,II)
 14     CONTINUE
        GO TO 19
 15     WRITE (6,33) (APER(N),DISDEN(N),N=361,365)
        DELTA1=DISDEN(37)-DISDEN(36)
        DELTA2=DISDEN(329)-DISDEN(328)
        DELTA3=DISDEN(92)-DISDEN(91)
        DELTA4=DISDEN(274)-DISDEN(273)
        Q90=DISDEN(36)+(DELTA1/2)
        Q10=DISDEN(328)+(DELTA2/2)
        Q75=DISDEN(91)+(DELTA3/4)
        Q25=DISDEN(274)-(DELTA4/4)
        IF(Q90.LE.0.) GO TO 16
        IF(Q75.LE.0.) GO TO 17
        GO TO 18
 16     WRITE (6,35)
        IF(Q90.LE.0.) Q90=0.001
        IF(Q75.NE.0.0) GO TO 18
 17     WRITE (6,36)
        IF(Q75.LE.0.) Q75=0.001
        GO TO 18
 18     RT1090=SQRT(Q10/Q90)
        RT2575=SQRT(Q25/Q75)
        WRITE (6,34) RT1090,RT2575
 19     CONTINUE
C       GRAPHS CURVES ON LOG-PROBABILITY SCALE
        INDEX1=NNM/3
        INDEX2=INDEX1*2
        DO 20 I=1,NNM
        DAS=DDS(I)/DRA
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      IF(DAS.LT.0.001) DAS=0.001
      YY=(ALOG10(DAS)*2.25)+6.75
      IC=2
      IF(I.EQ.1) IC=3
      XPER=APER(I)/100.
      IF(XPER.GE.1.0) XPER=.999
      IF(XPER.LE.0.001) XPER=.001
      CALL NDTRI (XPER,X,D,IER)
      IF(IER.NE.0) WRITE (6,31)
      XX=5.0+X*1.5
      IF(I.EQ.1) CALL NUMBER ((XX+0.02),YY,0.07,RNCNT,0.0,-1)
      CALL PLOT (XX,YY,IC)
      IF(I.EQ.INDEX1) CALL SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(I.EQ.INDEX2) CALL SYMBOL (XX,YY,0.035,1,0.0,-1)
      IF(XPER.GT.0.95.OR.XPER.LT.0.05) CALL SYMBOL (XX,YY,0.035,1,0.0,-1
     1)
   20 CONTINUE
      CALL NUMBER ((XX-0.07),YY,0.07,RNCNT,0.0,-1)
      IF(NOFLOW.GT.0) GO TO 21
      GO TO 24
C     INDICATES POSITION OF LAST NO FLOW WITH AN ASTERISK(IF NOFLOW>0)
   21 DO 23 I=1,NNM
      IF(DDS(I).GT.0.01) GO TO 23
      IF(DDS(I).LT.0.01.AND.DDS(I+1).GT.0.01) GO TO 22
      GO TO 23
   22 XPER=APER(I)/100.
      IF(XPER.LE.0.001) XPER=.001
      CALL NDTRI (XPER,X,D,IER)
      XX=5.0+X*1.5
      CALL SYMBOL (XX,-0.10,0.14,11,0.0,-1)
   23 CONTINUE
C        WRITES SUMMARY INFORMATION AT TOP OF PAGE FOR EACH CURVE
   24 CONTINUE
      CALL NUMBER (0.5,13.25,0.14,RNCNT,0.0,-1)
      CALL SYMBOL (1.0,13.25,0.14,STA,0.0,64)
      XPL=0.0
      GO TO 25
   25 CALL NUMBER ((XPL+0.5),12.5,0.14,RNCNT,0.0,-1)
      CALL NUMBER (XPL,12.25,0.07,DAYS,0.0,-1)
      CALL SYMBOL ((XPL+0.28),12.25,0.07,'DAYS PLOTTED',0.0,12)
      IF(NMISS.GT.0) GO TO 26
      IF(NOFLOW.GT.0) GO TO 27
      GO TO 28
   26 RMISS=FLOAT(NMISS)
      CALL NUMBER (XPL,12.0,0.07,RMISS,0.0,-1)
      CALL SYMBOL ((XPL+0.28),12.0,0.07,' DAYS MISSING DATA',0.0,18)
      IF(NOFLOW.EQ.0) GO TO 28
   27 ROFLOW=FLOAT(NOFLOW)
      CALL NUMBER (XPL,11.75,0.07,ROFLOW,0.0,-1)
      CALL SYMBOL ((XPL+0.28),11.75,0.07,' DAYS NO FLOW(*)',0.0,16)
   28 IF(NNM.NE.365) GO TO 29
      CALL SYMBOL (XPL,11.5,0.07,'(Q 10 /Q 90 ) 1/2 =',0.0,19)
      CALL NUMBER ((XPL+1.75),11.5,0.07,RT1090,0.0,2)
      CALL SYMBOL (XPL,11.30,0.07,'(Q 25 /Q 75 ) 1/2 =',0.0,19)
      CALL NUMBER ((XPL+1.75),11.30,0.07,RT2575,0.0,2)
      CALL PLOTE2
   29 RETURN
C
C
   30 FORMAT ('1','FLOW-DURATION CURVE FOR',17X,16A4,2X,F8.2,2X,'SQ.MI')
   31 FORMAT ('0',' * * * * * * * * * * * W A R N I N G  ERROR IN NDTRI')
   32 FORMAT (' ',4X,8(F6.2,1X,F6.3,3X))
   33 FORMAT (' ',4X,5(F6.2,1X,F6.3,3X))
   34 FORMAT ('0',7X,'THE RATIO (Q10/Q90)**1/2 =',F8.2,10X,'(Q25/Q75)**1
     1/2 =',F8.2)
   35 FORMAT (' ',' Q90 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANINGL
     1ESS.')
   36 FORMAT (' ','   Q75 IS LESS THAN OR EQUAL TO ZERO, RATIO IS MEANIN
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1GLESS.')
 END
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